S. A. E. JOURNAL

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W. R. Strickland, *President* Coker F. Clarkson, *Secretary* C. B. Whittelsey, *Treasurer*

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Aeronautic Progress Shown at Detroit

Leading Figures Among 767 Attendants at Dinner—Authoritative Papers on Technical Developments—Airport Activities and Aircraft Show Inspected

EACH successive Aeronautic Meeting of the Society reveals remarkable advances of the aeronautic industry, although only a few months have intervened between the latest meeting and its immediate predecessor. This fact was well exemplified at the Detroit Aeronautic Meeting and by the All-American Aircraft Show, which came only four months after the Chicago Aeronautic Meeting and Aircraft Show. Detroit was the Mecca of leading aircraft engineers, constructors, operators and aviators for the week of April 8 to 13. The Aeronautic Dinner on Tuesday night was attended by 767 members and guests of the Aeronautical Chamber of Commerce, the National Society and the Detroit Section; 105 exhibitors crowded Convention Hall with the greatest display of airplanes, engines and accessories so far held in this Country, and 142 late applications for space had to be turned down; and the Ford Airport was the scene all week of great activity that attracted hundreds of spectators daily.

The Aircraft Show was sponsored by the Detroit Board of Commerce and was managed by Ray Cooper, Secretary of the Board.

During the four days of the week the Aeronautical Chamber of Commerce held meetings of its commercial airplane manufactures' section and its flying-school technical committee, participated with the S.A.E. in the Aeronautic Dinner and in a general standardization conference that was held Wednesday afternoon.

Technical Sessions of Great Interest

The three technical sessions of the S.A.E. meeting on Wednesday, April 10, drew an attendance of 260, and absorbed attention was given to each of the excellent papers presented. The exposition by Dr. G. W. Lewis of the epochal cowling developed by the National Advisory Committee for Aeronautics and of the results obtained with slotted wings, by Lieut. C. B. Harper, was particularly noteworthy. Brigadier-General Gillmore's illustrated description of the research and development laboratories and work at Wright Field, given at the dinner, and Dr. Klemperer's most interesting and informative address on Gliding and Soaring Flights, at the Wednesday afternoon session, illustrated with films and slides, created great enthusiasm.

The General Standardization Conference held Wednesday forenoon was well attended also, and there was much interested discussion, following which the S.A.E. Aircraft-Engine and the Wheels, Rims and Tires Divisions of the Standards Committee held separate meetings.


LIEUT. C. B. HARPER TAKING OFF AT A STALLING ANGLE WITH AN AIRPLANE EQUIPPED WITH SLOTTED WINGS

Airport and Show Visited

About 200 S.A.E. representatives rode out to the Ford Airport in two motorcoaches and more than a dozen automobiles Tuesday forenoon and were shown through the Ford aircraft factory, had luncheon in the cafeteria of the Ford laboratory, and spent much time inspecting approximately 100 airplanes of many makes on the flying-field, where they were constantly taking off and landing. The visitors were then taken back in the motorcoaches and automobiles to the Aircraft Show and finally returned to the Book-Cadillac.

Who Made Meeting a Success

Members of the Society and their guests are indebted for the success of the various S.A.E. activities of the week to the following:

Capt. E. S. Land, Chairman of the Aeronautic Committee of the Society; Capt. L. M. Woolson, Chairman of the Detroit Aeronautic Meeting Committee and Chairman of the Detroit Section Aeronautic Division; W. C. Naylor, member of the Detroit Aeronautic Meeting Committee, Vice-Chairman of the Detroit Section Aeronautic Division and Chairman of the Technical Program Committee; W. B. Stout, member of the Detroit Aeronautic Meeting Committee; B. J. Lemon, Chairman of the Detroit Section; and Edward P. Warner, Chairman of the S.A.E. Aeronautic Committee and Chairman of the Aircraft Division of the Standards Committee.

How They Officiated

The Detroit Section officers and members of the Aeronautic Meeting Committee made the arrangements for the Aeronautic Dinner and

Meetings Calendar

1929			MAY			1929
SUN.	MON.	TUES.	WED.	THUR.	FRI.	SAT.
			1	2	3	4
5	6	7 CHICAGO	8 PENNSYLVANIA MILWAUKEE CANADIAN	9 NORTHERN CALIFORNIA	10 SOUTHERN CALIFORNIA	11
12	13 CLEVELAND DETROIT	14 DAYTON	15	16	17 PENNSYLVANIA	18 INDIANA NORTHWEST
19	20	21 S.A.E. CLUB OF COLORADO	22 NEW ENGLAND	23 METROPOLITAN	24	25
26	27	28 WASHINGTON	29	30	31	

National Meetings

Summer—June 25 to 28
Saranac Inn, Saranac Lake, N. Y.

Western Aeronautic—August
Wichita, Kan.

Cleveland Aeronautic—Aug. 26 to 28
Hollenden Hotel, Cleveland.

Production—Oct. 2 to 4
Hotel Cleveland, Cleveland.

Transportation—November
Philadelphia or Toronto.

Annual Dinner—Jan. 9, 1930
New York City.

Annual—Jan. 21 to 24, 1930
Book-Cadillac Hotel, Detroit.

Section Meetings

Buffalo—May
High Speed Oil Engines—E. C. Magdeburger, Bureau of Engineering, Navy Department.
Motor Rail Cars—Charles Guernsey, J. G. Brill Co.
Distillate Fuels—E. Wanamaker, Rock Island Lines.

Canadian—May 8
Dinner Meeting.

Chicago—May 7
Aeronautic Meeting—Aerial sightseeing, stunt and formation flying at 63rd St. Flying-Field. Dinner at City Club.
The Greenland Flight—Bert H. Hassel.
Flying Experience—Lieut. A. J. Williams, U. S. N.

Cleveland—May 13
Modern Progressive Production Methods—H. S. McClellan, Chrysler Corp.

S.A.E. Club of Colorado—May 21
Pistons—Edward Wyman, Chrysler Agency.

Dayton—May 14
Ladies' Night.

Detroit—May 13

Indiana—May 18
Racing Rules and Cars of 1930—Symposium by E. S Rickenbacker, T. E. Myers and F. S. Duesenberg.

Metropolitan—May 23
Experiences and Lessons Learned in Aviation—W. E. Boeing, Pacific Air Transport.

Milwaukee—May 8
Waukesha Motor Co. Plant.

New England—May 22
Motorboat Meeting—Boston Yacht Club—Joint Meeting with New England Outboard Motor Boat Association—Exhibition and Demonstrations; Dinner at Massachusetts Institute of Technology.
Outboard Racing—Frank Wigglesworth.
Outboard Engines—Mr. Wilkinson.
Outboard Hulls—Jacob Dunnell.

Northern California—May 9

Northwest—May 18
Seattle, Wash.
Plain-Tube Carburetion—C. A. O'Neill, Stromberg Motor Devices Co.

Pennsylvania—May 8
Aeronautic Meeting.
Comprehensive Planning of Modern Airports—Francis Keally, Columbia University.
Practical Airport Operation—E. A. Johnson, Johnson Airplane Supply Co.

Pennsylvania—May 17
Golf Meeting—Tredyffrin Country Club.

Southern California—May 10
Small Aircraft-Engines—N. N. Tilley, Kinner Airplane & Motor Corp.

the entertainment program. Mr. Naylor assumed responsibility for the Airport inspection trip, for which the American Car & Foundry Co. provided the two motorcoaches, the Packard Motor Car Co. furnished a dozen limousines, and a number of local members loaned their private cars. He also served as chairman at the Wednesday afternoon technical session. Mr. Stout introduced the guests at the Dinner, Mr. Warner presided as toastmaster and as chairman at the Wednesday evening technical session, and also at the General Standardization Conference.

For the most interesting and very informative papers presented at the Dinner and at the two technical sessions the most hearty thanks of the attendants are due to the authors and speakers, Brig.-General W. E. Gillmore, F. P. Wills, Dr. Wolfgang Klemperer, Dr. G. W. Lewis, and Lieut. C. B. Harper. The papers will be published in an early issue of the S.A.E. JOURNAL.

Full news reports of the various meeting activities appear in the immediately succeeding pages and the continuation therefrom.

Exhibits at Airplane Show

Notable Advance Reflected by Displays of Wide Variety of Types and Sizes

NO WRITTEN description can convey an adequate idea of the Detroit All-American Aircraft Show. The only way to get a comprehensive and detailed idea of the present status of the aircraft industry is to spend much time in person at such an amazing display. Realizing this, the local and visiting men in the automotive industry spent what time they could during the week at the show, which drew a large attendance daily.

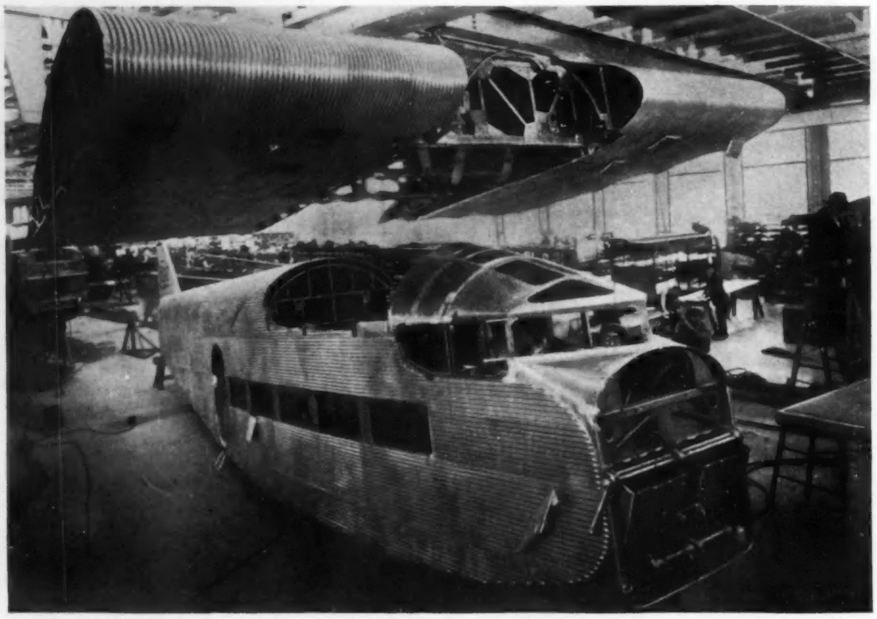
Convention Hall is not well suited for such an exhibition because of the low roof, the numerous pillars and general lack of spaciousness. For this reason several of the largest airplanes could not be accommodated and had to be displayed in other buildings. Also, more applicants had to be refused space than were accepted. Airplanes were displayed in various places about the city, some in hotel lobbies and others in the smaller public parks.

Trends in Design Indicated

The Airplane Show was notable for the absence of freakish design, every craft exhibited, from the primary glider shown by the Embry-Riddle Flying School, of Cincinnati, to the Ford 14-passenger transport bought by the Stout Air Services for the Cleveland-Detdoit-Chicago lines, being a practical machine. Marked advance in design and workmanship was evident, although great diversity of types and models gave very interesting variety to the display. Decorators had done a good job in making the interior of the building attractive with bunting, flags and potted palms. Visitors were afforded ample opportunity to examine all the airplanes closely.

Monoplanes largely predominated over biplanes; cabin models prevailed over open types; air-cooled radial engines were well in the ascendency; more streamlining of fuselages than heretofore was observable; several seaplanes were displayed, and tendencies toward the adoption of inverted and in-line engines, the N.A.C.A. type of low-drag cowl and slotted wings were indicated. Extension and development of commercial airlines was reflected by the relatively large number of multi-passenger cabin models, one at least rather elaborately equipped with sleeping berths, sitting and dining compartment, and lavatory. Some of the more notable exhibits were as follows:

AIRPLANE VIEW OF FORD AIRPORT, DETROIT, THE SCENE OF GREAT FLYING ACTIVITY DURING AIRPLANE WEEK
In the Foreground, from Left to Right, Are the Ford Airplane Factory, the New Hangar, the Old Hangar, and, in the Right Middle-Ground, the Passenger Terminal from Which the Air Transport Planes Take Off for Chicago and Cleveland. In the Center Background Is the Airship Mooring-Mast



LOWERING INTO PLACE THE MAIN SECTIONS OF THE THICK MONOPLANE WINGS IN THE ASSEMBLING OF AN ALL-METAL TRI-MOTOR FORD PASSENGER AIR-TRANSPORT

Some Noteworthy Exhibits

Keystone-Loening amphibian biplane, to be used by the Thompson Aeronautical Corp. for passenger, express and mail service

Vought Corsair amphibian biplane

Eastman Sea Rover seaplane with a six-cylinder radial engine mounted in the leading edge of the monoplane wing over the open cockpit

Mohawk twin-engine cabin monoplane with inverted four-cylinder in-line engines mounted in the leading edge of the wings

Lone Eagle biplane with inverted four-cylinder in-line engine, shown by the Moundsville Airplane Corp.

Boeing-Hamilton all-metal two-float cabin seaplane and a land monoplane, displayed by the United Aircraft & Transport Corp.

New Boeing metal mail plane and an express biplane, exhibited by the Boeing Airplane Co.

Fokker tri-motor de luxe transport, a Fokker Super-Universal and a six-passenger cabin high-wing monoplane

Cabin section of a Ford 12-passenger transport provided with berths, sitting compartment and lavatory; and a Ford 14-passenger transport to be used on the Cleveland-Detroit-Chicago airlines of the Stout Services

American Eagle sesquiplane with folding wings; also an unsheathed fuselage frame of tubular construction

Cunningham-Hall all-metal four-passenger cabin biplane

Kreutzer four-passenger tri-motor air coach

Curtiss Super-Robin three-place cabin monoplane, shown by the Curtiss Robinson Airplane Co.

Pitcairn United States Mail biplane and Lockheed Vega monoplane, each fitted with the N.A.C.A.-type cowling, the latter model exhibited by the Schlee-Brock Aircraft Co.

Stinson Wasp, built with a sound-proof cabin; and a Stinson Junior and a Stinson Detroiter cabin model

Whittelsey Avian biplane with folding wings fitted with Handley Page slots and driven by a four-cylinder in-line air-cooled engine; and the Avro Avian flown by Lady Heath from Cape Town, South Africa, to London, now owned by Amelia Earhart, who flew it from New York City to Los Angeles and return

Barling dihedral low-wing monoplane, with five-cylinder radial engine

Fairchild high-wing cabin monoplane and a two-passenger low-wing open-cockpit monoplane

Great Lakes combination training and sport biplane powered by a Cirrus four-cylinder in-line air-cooled engine and mounted on a large rotating turntable

Wright Wasp and Hornet engines, some shown with N.A.C.A. cowling, and this low-drag cowl shown separately

Bellanca high-wing cabin monoplane

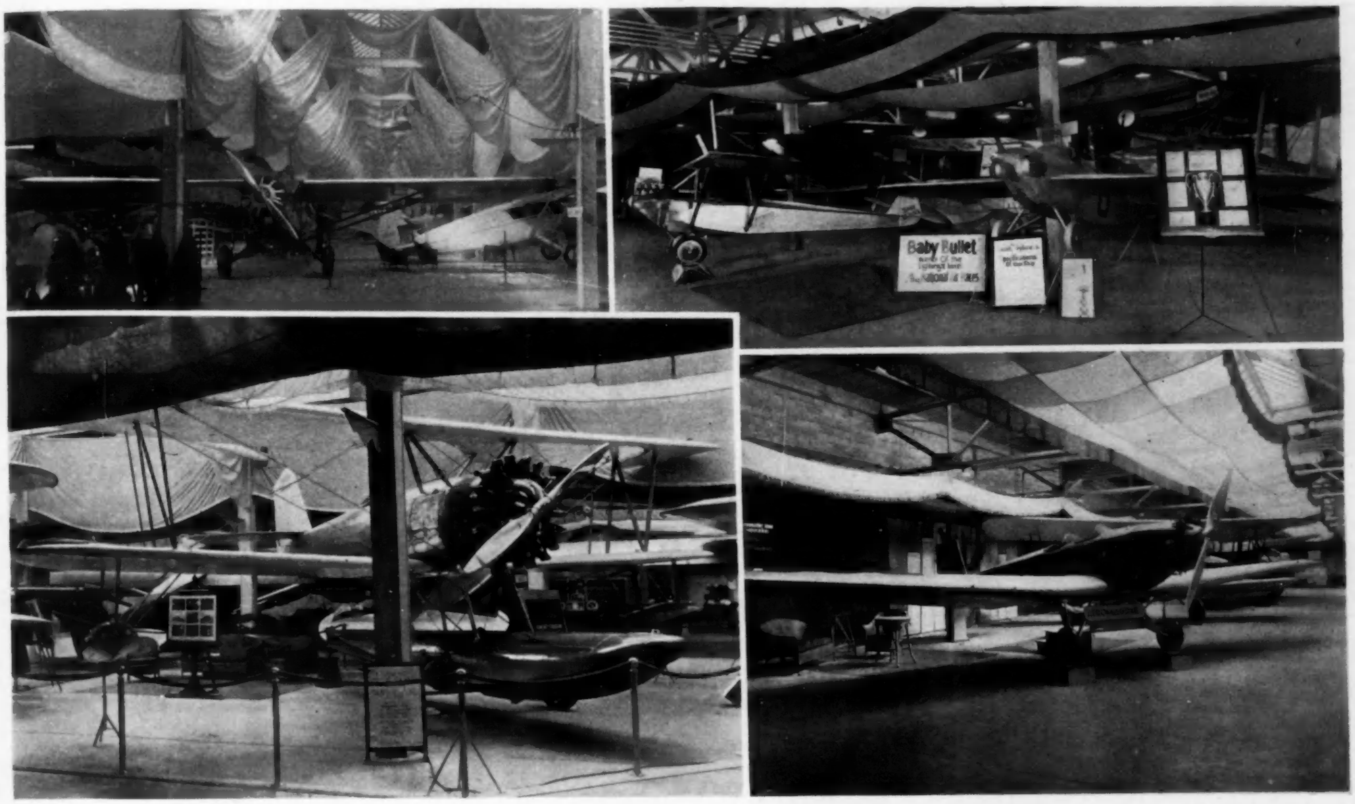
Isotta-Fraschini V-type water-cooled 12 and 18-cylinder aeronautic engines, and 6-cylinder in-line and 12-cylinder V-type air-cooled engines.

S.A.E. Aircraft-Show Exhibit

IN ADDITION to conducting the Aeronautic Meeting, the Society maintained a booth at the All-American Aircraft Show for the purpose of exhibiting the practical application of aeronautic standards to various parts and equipment.

The most impressive part of this exhibit was the three crankshafts from the Curtiss Conqueror, the Pratt & Whitney Wasp, and the Wright J-6 engines, each having an S.A.E. Standard No. 30 Shaft-End. One propeller-hub fitting all of these shaft-ends was exhibited to demonstrate the interchangeability accomplished. Two makes of generator showing the S.A.E. Standard Generator Mounting-Flange; four makes of fuel pump with the S.A.E.

NIGHT VIEW OF FORD AIRPLANE FACTORY WHICH WAS INSPECTED BY S.A.E. MEMBERS ATTENDING THE AERONAUTIC MEETING



GENERAL VIEWS OF ALL-AMERICAN AIRCRAFT SHOW IN DETROIT THE WEEK OF THE MEETING

Convention Hall Was Crowded to the Maximum with the Attractive Displays of 105 Exhibitors of Complete Airplanes, Engines and Accessories. The Airplanes Ranged from Gliders and Diminutive Single-Seat Monoplanes to Tri-Motor 14-Passenger All-Metal Transports and a High-Speed Amphibian

Standard Fuel-Pump Mounting-Flange; two makes of starting motor with the S.A.E. Standard Starter-Flange, and two makes of aeronautic storage-battery conforming to the S.A.E. Aeronautic Storage-Battery Standards completed the exhibit.

The display attracted a great deal of attention and was the means of establishing contact with a large number of interested engineers. Approximately 60 prospective members called to inquire about membership, and of this number 10 left applications at the booth. The names and addresses of the others have been turned over to the Membership Increase Department of the Society and it is anticipated that many more will eventually file applications. The booth was also visited during the 10 days by more than 50 members of the Society, many of whom made it their headquarters at the show.

The crankshafts on exhibition were loaned by the Curtiss Aeroplane & Motor Co., the Pratt & Whitney Co., and the Wright Aeronautical Corp.; the propeller-hub by the Standard Steel Propeller Co.; the storage batteries by the Electric Storage Battery Co. and the Willard Storage Battery Co.; the generators by the Leece-Neville Co. and the Eclipse Machine Co.; the starters by the Heywood Starter Corp. and the Eclipse Machine Co.; the fuel pumps by the A. C. Spark Plug Co., the Pioneer Instrument Co., the McCord Radiator Mfg. Co., and the National Steel Products Co. We hereby acknowledge our appreciation.

It is anticipated that at future National aeronautic shows the Society will be able to provide similar headquarters for the members and interested engineers, and also further displays of the progress being made in aeronautical standardization.

Airport Activity Draws Crowd

Party of About 200 Sees Much of Interest on Flying Field and in Ford Factory

UPWARD of 200 meeting-attendants availed themselves of the opportunity afforded on the first morning of the meeting to visit Ford Airport and the Ford aircraft factory. Boarding two motorcoaches and more than a dozen automobiles loaned for the occasion by the American Car & Foundry Co., the Packard Motor Car Co., and local S.A.E. members, they were driven directly from the Book-Cadillac to the airport under motorcycle police escort. Upon arriving at the airport passenger-terminal, the visitors were provided with guides and led on an inspection trip through the airplane factory.

Great interest was shown by the visitors in the dozen Ford all-metal tri-motor planes in process of assembly in the front center portion of the factory building, and in the systematic layout of fabricating tables, jigs and fixtures for structural members and subassemblies. The rear portion of the factory is devoted to the cutting and forming of minor parts, and alternating with the work-tables and fixtures ranged along either side toward the front of the building are stock-shelves, all systematically arranged for progressive operation and plainly labeled with stock-identification numbers.

Assembling the Major Parts

Fuselage frame-sections, wing trusses, complete wing-sections and tubular engine-supports are assembled progressively along either side to be

BRIGADIER-GEN. W. E. GILLMORE

Chief of Materiel Division, Air Corps, Wright Field, Speaker at the Aeronautic Dinner

available at the points where needed for assembly of the airplanes. When the trusses of the wing sections have been covered with the corrugated duralumin skin, they are hoisted by tackle, swung over above the assembled fuselage and lowered into position as one of the later assembling operations. Engines and other heavy parts are handled by a Fordson-tractor crane.

Many of the visitors doubtless would have been glad to spend a day in the plant watching operations, but the inspection was made at the factory lunch-period and could not be prolonged, as there were about 100 airplanes out on the airport to be seen and a still larger number on exhibition at the Aircraft Show before the start of the Aeronautic Dinner at 6:30 p.m.

Slotted-Wing Flights and Gliding

Many sorts of airplane were disposed about the airport field, from the smallest single-seat monoplane to three-engined passenger transports. These were constantly taking off and landing, half a dozen or more being in the air simultaneously. Among more interesting incidents were demonstrations of the action of wing slots by Lieut. C. B. Harper in taking off and landing in a short distance and in recovering from a stall or a spin; glider trials with a glider towed by a Ford car; and the departure of a Ford Airline transport for Chicago with a load of passengers and their luggage. Considerable attention was bestowed also on the new N.A.C.A.-type cowling on several airplanes.

The visiting members were driven in the motorcoaches to the Ford experimental laboratory for luncheon in the cafeteria, thence back to the passenger terminal, to the Aircraft Show, and finally to the Book-Cadillac.

Dinner Meeting Swamps Ballroom

Aviatrices of Three Nations Among Guests—Lieutenant Havill Awarded Medal—General Gillmore Speaks

WHEN members and guests of the Society assembled Tuesday evening at 6.30 for the Aeronautic Dinner they overflowed the grand ballroom of the Book-Cadillac and more than 50 of the 767 could not be seated at tables on the main floor or in the balcony but had to content themselves as best they could at tables set up in the crystal room. After appetites whetted by the day's inspection trip to Ford Airport and the All-American Aircraft Show at Convention Hall had been appeased, these unfortunates assembled with the main body in the grand ballroom, after the tables were removed, to enjoy the program of professional dancing, singing and music provided by the Detroit Section and to hear the addresses.

The room was appropriately and attractively decorated with the National colors, a spot-light was directed upon a miniature airplane suspended from the center of the ceiling with its propeller whirling, and two pairs of loud-speakers of the Society's public-address system enabled everyone to hear all the speeches without effort.

AERIAL VIEW OF WRIGHT FIELD, DAYTON, OHIO, SHOWING MAIN LABORATORY IN RIGHT FOREGROUND

SOME OF THE PROMINENT PARTICIPANTS IN THE DETROIT AERONAUTIC DINNER AND TECHNICAL SESSIONS

(1) Edward P. Warner, Toastmaster at the Dinner and Chairman of the Second Technical Session; (2) Miss Amelia Earhart, One of the Three Aviatrix Guests at the Dinner; (3) Lieut-Commander Clinton H. Havill, U. S. N., Who Was Presented with the Wright Brothers Medal for the Best Paper on an Aerodynamic Subject Delivered before the Society in 1928; (4) Capt. L. M. Woolson, Chairman of the Detroit Section Aeronautic Division and Chairman of the Detroit Aeronautic Meeting Committee; (5) Capt. E. S. Land, Chairman of the S.A.E. Aeronautic Committee; (6) B. J. Lemon, Chairman of the Detroit Section, Which Sponsored the Aeronautic Dinner and Entertainment

Stout Introduces Guests

A score of distinguished guests were seated at a long speakers'-table on a platform at one side of the room. These guests were introduced by William B. Stout, who evoked a general laugh when he referred to the three lady guests as "the most charming aviatrices of Canada, Germany and our own Country." Those introduced and individually applauded were:

George Haldeman, who flew to the Canaries with Ruth Elder

Thea Rasche, the German aviatrix

Clarence D. Chamberlin, who flew the Atlantic with Charles A. Levine

Helen McGregor, the Canadian aviatrix

Professor Hobbs, the University of Michigan meteorologist, who established the weather station in Greenland

Dr. George W. Lewis, director of aeronautical research, of the National Advisory Committee for Aeronautics

Amelia Earhart, the American aviatrix

Reed Landis, American war ace and chairman of the National Aeronautic Committee of the American Legion

Brig.-Gen. W. E. Gillmore, assistant chief engineer of the Air Corps

J. Don Alexander, builder of Eagle Rock airplanes in Denver

E. S. Evans, president of the National Glider Association

Charles L. Lawrance, designer of the Wright Whirlwind and Cyclone engines

Frank H. Russell, vice-president of the Curtiss Aeroplane & Motor Co.

W. B. Mayo, chief engineer of the Ford Motor Co.

Herr Hentzen, of the Air Ministry of Germany

Anthony H. G. Fokker, designer and manufacturer of Fokker airplanes

R. B. C. Noorduyn, assistant to Mr. Fokker

Lester D. Gardner, president of Aeronautical Industries

William E. Metzger, retired automobile manufacturer of Detroit

(*Continued on p.* 547)

Chronicle and Comment

William C. Naylor

COMING within a few days after the conclusion of the Detroit Aeronautic Meeting in which Mr. Naylor took so active a part, the news of his accident at Ford Airport on April 13 and its fatal termination three days later came as a particularly poignant shock to members who had so recently sat at table with him and in the session at which he was chairman. Although he had been a member of the Society for only a little more than two years, Mr. Naylor had taken a very active part in its aeronautic activities and had been nominated Chairman of the Detroit Section Aeronautic Division, the members of which will feel his loss very keenly. He had created by his ability and agreeable personality a high appreciation of his services and character, both as an aeronautic engineer and as a cooperator in the affairs of the Society.

Wichita Aeronautic Meeting

THE AERONAUTIC Committee is now arranging the technical program for the next aeronautic meeting of the Society, which will be held in Wichita, Kan., during the week of the Wichita Aircraft Show early this summer.

Second Vice-President W. B. Stout will discuss the plans for the meeting at a conference of aeronautic engineers to be held at the Lassen Hotel in Wichita on May 1. Mac Short, chairman of the local committee in charge of the Wichita meeting, is making arrangements for the conference, all aeronautic engineers and executives within flying distance being invited.

The organization of an Aeronautic Section of the Society with headquarters at Wichita will also be discussed, this having been suggested by several members. With 10 manufacturers of aircraft in Wichita and as many more within one or two hours' flying distance, Wichita is a logical center for an Aeronautic Section of the Society. For this reason the Aeronautic Committee approved the holding of the second Aeronautic Meeting of the Society this year in Wichita, the Western Aeronautic Meetings during 1927 and 1928 having been held in Spokane and Los Angeles respectively.

The Aeronautic Engineering Department

AN AERONAUTIC Engineering department is initiated with the present issue of THE JOURNAL, beginning on p. 537. This is in accordance with the plans for reorganizing the Society along the lines of engineering interests and activities of the members. It will also provide for segregating news and reports of aeronautic engineering activities in one part of THE JOURNAL where members will become accustomed to look for them. In the new department this month will be found the report on aeronautic standards considered at the Detroit Conference last month, advance notice of authors and papers for the Wichita and Cleveland Aeronautic Meetings authorized by the Aeronautic Committee, and reports of the aeronautic meetings of the Metropolitan, Milwaukee, Northern California and Canadian Sections in April.

As reported in the news account of the meeting of the Aeronautic Committee during the Detroit Aeronautic Meeting last month, the Committee authorized appointment of an Aeronautic Research Committee and an Aeronautic Membership Committee. The former is expected to take over the aircraft-lighting investigation and the latter to cooperate with the present Membership Committee of the Society in increasing membership of aeronautic engineers. News of the work of these Committees, when appointed, will also be chronicled from time to time in the new department.

Pittsburgh Section Proposed

AT AN INFORMAL luncheon conference of 14 members of the Society, held at the William Penn Hotel on April 19, it was generally agreed that there should be a local Section of the Society in western Pennsylvania, with headquarters in Pittsburgh. A detailed account of the conference, which was sponsored by N. G. Bjorck, of the Lang Motor Truck Co., appears on p. 556 of this issue.

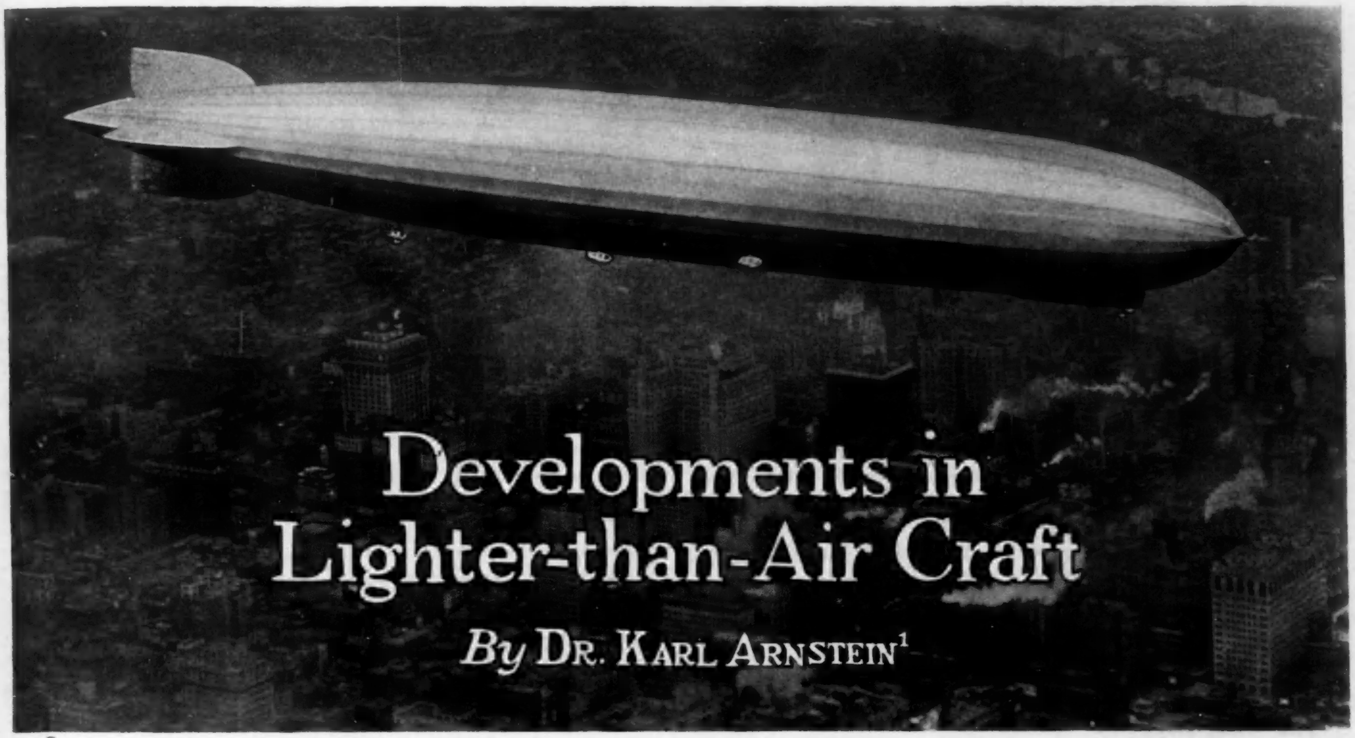
With more than 80 members of the Society located in the City of Pittsburgh and with the interest displayed at the meeting, there is every indication that local Section activities there will be most successful.

May 20 Is the Deadline

ORDER blanks for Part I of the 1928 S.A.E. TRANSACTIONS were mailed to members residing in the United States with the last *Meetings Bulletin*. These blanks are in the form of business reply cards on which the postage is paid by the Society so that a member desiring a copy of this Part of S.A.E. TRANSACTIONS has only to write his name and address in the spaces provided and mail the card. To ensure receiving your copy, "Do it now," while it is in mind.

Members living outside of the continental United States had order blanks mailed to them early last month. This will, in the majority of cases, give sufficient time for them to sign and return the blanks before the closing date for the receipt of orders.

This Part, which will be sent free of charge to members ordering copies, contains all material printed in the S.A.E. JOURNAL from January to June, 1928, inclusive, which has been selected by the Publication Committee as possessing sufficient engineering merit to warrant reprinting in the permanent record of the Society. The printing order will be based on the number of blanks returned by May 20, and copies cannot be guaranteed to those whose orders are not received at the office of the Society in New York City on or before that date.



Developments in Lighter-than-Air Craft

By DR. KARL ARNSTEIN[1]

CHICAGO AERONAUTIC MEETING PAPER — *Illustrated with* PHOTOGRAPHS AND DRAWINGS

NOTABLE developments in 1928 that have greatly increased interest in lighter-than-air craft were the transatlantic flight of the Graf Zeppelin as an experiment in commercial transoceanic air-service, the ordering by the United States Navy Department of the construction in this Country of two rigid airships larger than any yet built or under construction, the development and construction of two British airships for long-distance passenger and mail transportation, the starting of erection of the world's largest airship factory and dock at Akron, Ohio, and the construction and operation in this Country of a number of non-rigid airships to be used for commercial purposes.

Each of these developments is dealt with in order. General dimensions, major characteristics, and unique features of the Graf Zeppelin, the new Navy airships, and the projected large transoceanic commercial airships are given. Alternative lifting-gas and fuel-gas cell arrangements are shown, means of water recovery from the combustion of liquid fuel to compensate for weight loss as the fuel is consumed are discussed, and the advantages of helium as a lifting gas are pointed out. Use of this non-inflammable gas makes possible the placing of engines and passenger quarters inside the hull. Another unique feature of the projected American airships is the use of swiveling propellers that can be swung through an arc of 90 deg. and used to elevate or depress the ship. Main transverse rings of the hull are described as being of built-up triangular section with longitudinal corridors that give the crew ready access to all parts of the hull for inspection.

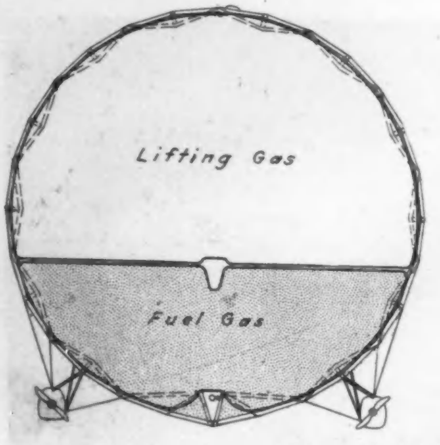
The dock in which the new ships will be built is of special design, and actual distribution of wind pressures has been taken into account.

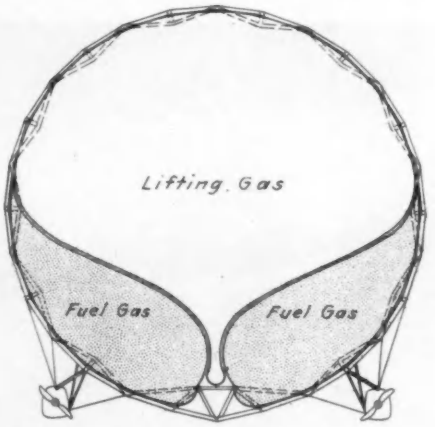
Brief descriptions are given of the British 5,000,000-cu. ft. hydrogen airships to be completed this summer, and of the two non-rigid passenger-airships, the Pilgrim and the Puritan, which have demonstrated the advantages of their type for both commercial and military purposes.

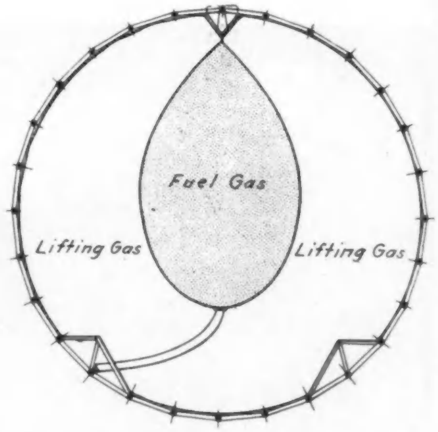
Conceding the importance of the airplane for high-speed mail and passenger transportation over medium distances, the author emphasizes the utility of lighter-than-air craft for long range, large-capacity mail, passenger and freight air-service.

SEVERAL important developments in 1928 have given considerable impetus to the growth of the lighter-than-air craft industry. Chief among these developments were (*a*) the first experiments with a commercial transatlantic air-service by means of the rigid airship Graf Zeppelin; (*b*) authorization by the United States Navy Department for the construction of two rigid airships of 6,500,000-cu. ft. capacity by the Goodyear-Zeppelin Corp.; (*c*) development and construction by the British of two 5,000,000-cu. ft. airships to be used for long-distance passenger and mail transportation; and (*d*) erection of the world's largest airship factory and dock by the Goodyear-Zeppelin Corp. in Akron, Ohio; and construction by the same company of a fleet of small non-rigid airships to be used for commercial purposes.

[1] Vice-president, Goodyear-Zeppelin Corp., Akron, Ohio.







VARIOUS ARRANGEMENTS OF AIRSHIP LIFTING-GAS AND FUEL-GAS CELLS

Fig. 1—Cross-Section Through Cells of the Graf Zeppelin, Showing Central Corridor Between the Lifting-Gas and Fuel-Gas Cells of the Ship

Fig. 2—Alternative Arrangement, with Fuel Gas-Cells Below and on Either Side of the Lifting-Gas Cell and with Corridor at Base of Hull

Fig. 3—Arrangement with Fuel-Gas Cells Suspended in the Center and Completely Surrounded by Non-Inflammable Helium-Gas Cells

These developments will be discussed in the foregoing order with regard to the effect each has upon the development of the art as a whole.

Major Features of the Graf Zeppelin

The Graf Zeppelin was built with the definite purpose of extending the commercial overland flight service, which the Zeppelin company instituted as early as 1911, into the entirely new field of commercial transoceanic air transportation. Almost 30 years ago Count Zeppelin realized that rigid airships were predestined for transoceanic work. The developments of later years, along with theoretical research, have shown that the large rigid airship stands out as superior to all other forms of aircraft when due consideration is given to safety and reliability, comfort of travel, and regularity and economy of service.

Although all investigations had indicated that a 5,000,000-cu. ft. hydrogen ship was the smallest that was practical for the proposed service, the German Zeppelin company found itself limited as to size and fineness ratio by the size of the available construction hangar. Therefore the hydrogen capacity of the Graf Zeppelin was made 3,710,000 cu. ft.; the length, 770 ft.; and the diameter, 100 ft. Propulsion is by five 530-hp. engines, a total of 2650 hp., giving a top speed of 78 m.p.h.

At this speed the cruising radius is about 5360 miles, while at a cruising speed of 70 m.p.h. the range is increased to 7030 miles. These figures apply to the ship carrying 20 passengers and 5 tons of freight in addition to a crew of 40. In fundamental design this ship follows in general the conventional principles embodied in its immediate predecessor, the Los Angeles.

One novel feature incorporated into this new ship must be considered as a definite step in the proper direction. This is the adoption of gaseous fuel. Previous ships, flying with liquid fuels, grew lighter during flight as the fuel was consumed and therefore had to valve out some of the lifting gas to reestablish equilibrium; for instance, to land after a long flight. The designers of the Graf Zeppelin selected a fuel gas having the same density as air so that the consumption of fuel would not lighten the weight of the ship. The ship is, therefore, always in static equilibrium, and the valving of hydrogen is not necessary.

It had also been the practice in previous ships to retain the lifting gas within cylindrical cells which, when fully inflated, completely fill the hull. But in the Graf Zeppelin the lower third of the hull volume has been given over to an additional set of cells in which the fuel gas is carried. This arrangement is shown in Fig. 1. The lifting-gas cells occupy the available hull space above the fuel-gas cells. A central gangway, suspended from the wire bracing of the main rings, passes through the ship between the upper and the lower gas cells. Such a corri-

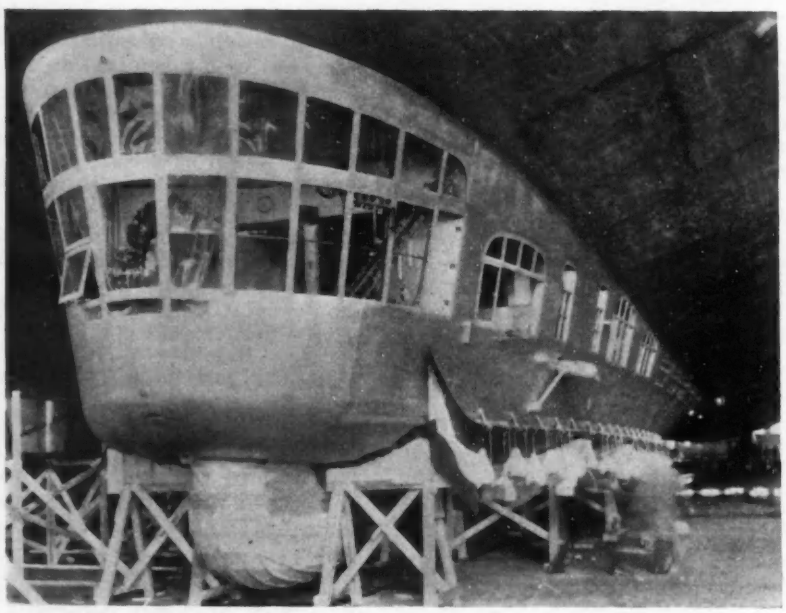


FIG. 4—PILOT CAR AND PASSENGER CABIN OF THE GRAF ZEPPELIN

dor is necessary to facilitate the inspection of the lifting-gas cells. It also provides a means of investigating the fullness of the fuel-gas cells both during inflation and in flight. Such an additional corridor does not materially increase the weight of the ship structure as a whole, as a compensating saving in weight of the main rings is possible because of the supporting effect of the central corridor on the main-ring bracing.

An alternative arrangement to provide for the carrying of fuel gas and yet obviate the need for an additional inspection corridor is illustrated in Fig. 2. The fuel-gas cells occupy the air space at both sides of the corridor, being attached tangentially to the structure in the neighborhood of the equator. Cells for the lifting gas occupy the central and upper portions of the hull. As helium airships are not fully inflated at the beginning of a flight, space being left for the gas to expand as the ship climbs or the temperature rises, a part of this space is available for the installation of a fuel-gas carrying system, as indicated in Fig. 2. Since the weight of gasoline is saved through the use of fuel gas, the lifting-gas cells may be still less inflated, yielding space for additional fuel gas.

Use of the inert gas, helium, as a lifting medium, makes possible an entirely fireproof arrangement such as that suggested by Fig. 3, in which the fuel-gas cells are suspended from the upper corridor and hang completely within the lifting-gas cells.

Transatlantic Flight and Its Lessons

The Graf Zeppelin made her flight from Friedrichshafen, Germany, to Lakehurst, N. J., over a route of 6000 miles in 112 hr. She is shown in flight over Philadelphia in the photograph used for the heading of this paper. The general details and experiences of the flight are well known. Unsatisfactory meteorological conditions existing over the North Atlantic made it desirable to utilize the advantage of the airship which permits the circumnavigation of areas of atmospheric depression. The commander succeeded in dodging the main storm area but encountered several squalls of small area but high magnitude. The trip was therefore a severe test of the ship's strength. Several of the fastenings on the port horizontal fin probably were not strong enough to hold the fabric in place during one of these squalls, with the result that some of the covering was torn away. Emergency repairs were made in flight in mid-ocean, however, which convincingly demonstrates the advantage of the airship, which does not depend upon its forward motion for lift but can be slowed down at will.

On the return trip, which was accomplished in 69 hr., the ship ran into an area of depression over Newfoundland. It is reported that she encountered storms of approximately the velocity of the ship's speed, which at times made forward progress on the course impossible.

Several important lessons can be learned from these flights. It is evident that even airships built along conventional lines are capable of withstanding abnormal weather conditions. It seems imperative, however, that if regular service is to be maintained ships must have higher speeds; and, since a fast and regular service will not permit the circumnavigation of any but the worst storms, it is advisable that they be built more

Fig. 5—Hull of the Graf Zeppelin Under Construction at Friedrichshafen, Germany

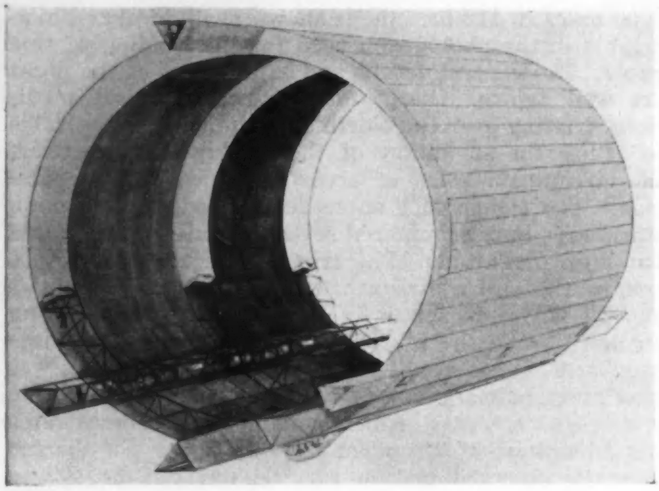


FIG. 6—SCHEME OF TRIANGULAR MAIN-RING STRUCTURE OF 6,500,000-CU. FT. AIRSHIPS ORDERED BY THE UNITED STATES NAVY

Each Ring Gives Access by Members of the Crew to All Longitudinal Corridors and All Parts of the Hull

rugged and compact, to withstand the strain from repeated stresses that may be encountered in the gusts of heavy gales. The Graf Zeppelin has also taught us that such passenger accommodations as she has are not quite as commodious or comfortable as the ocean traveling public would expect on regular lines. The officers' navigating room and the passenger cabin are shown in Fig. 4, while the ship is shown under construction in Fig. 5. The Graf Zeppelin illustrations herewith are used by courtesy of the Luftschiffbau Zeppelin.

Hull Structure of Large Airships

It is extremely fortunate that the United States Navy, in its recent order for the construction of two large rigid airships, has had the vision to select a size and type that are exceedingly suitable for a long-distance commercial vehicle. The new ships are to be helium inflated and have a gas capacity of 6,500,000 cu. ft. This size of helium ship is comparable with hydrogen-inflated ships of a little less than 5,000,000-cu. ft. capacity. This difference in capacity is explained by the lower lifting power of helium and the necessity of inflating the bags only so much that no gas will be lost as a result of subsequent expansions in maneuvering.

Some idea of the hull structure employed on this type of ship is given in Figs. 6 and 7. The main rings are built-up transverse frames of corridor cross-section, strong enough to take all the stresses without the assistance of wire bracing. The location of the two lower corridors at an angle of 45 deg. with the vertical axis contributes considerably to the support of the auxiliary rings and hence to the general structural strength of the assembly. The triangular section of the main rings has a great number of advantages over that of the flat rings used in smaller ships. The triangular rings afford means for communication between longitudinal corridors, as illustrated in Fig 6; and, together with these corridors, make possible a thorough inspection of the ship. They provide supports for installation of the power cars completely within the hull, with a consequent saving of air resistance; afford access for quick repair and continuous inspection of the engines; and

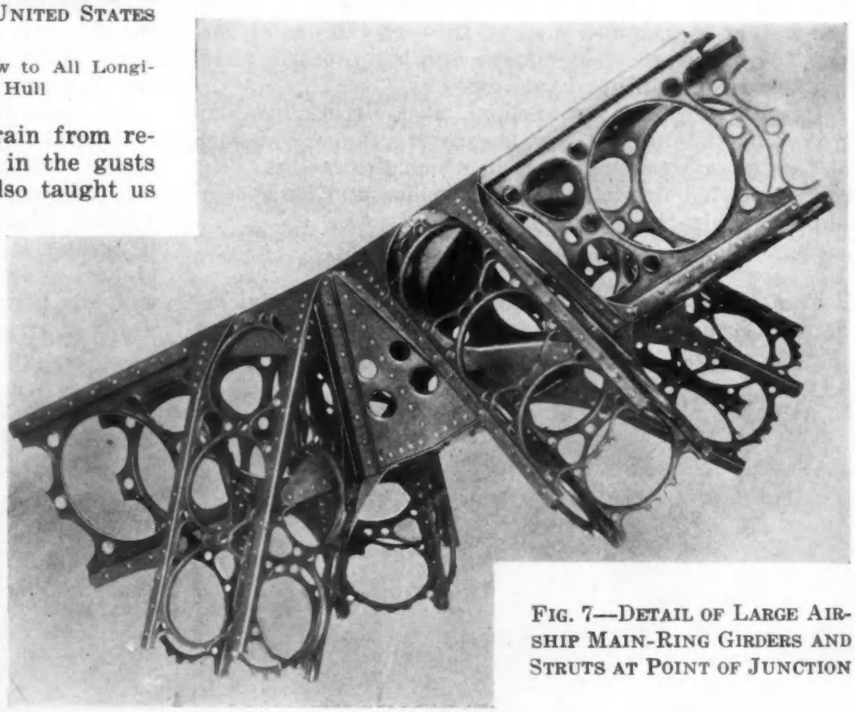


FIG. 7—DETAIL OF LARGE AIRSHIP MAIN-RING GIRDERS AND STRUTS AT POINT OF JUNCTION

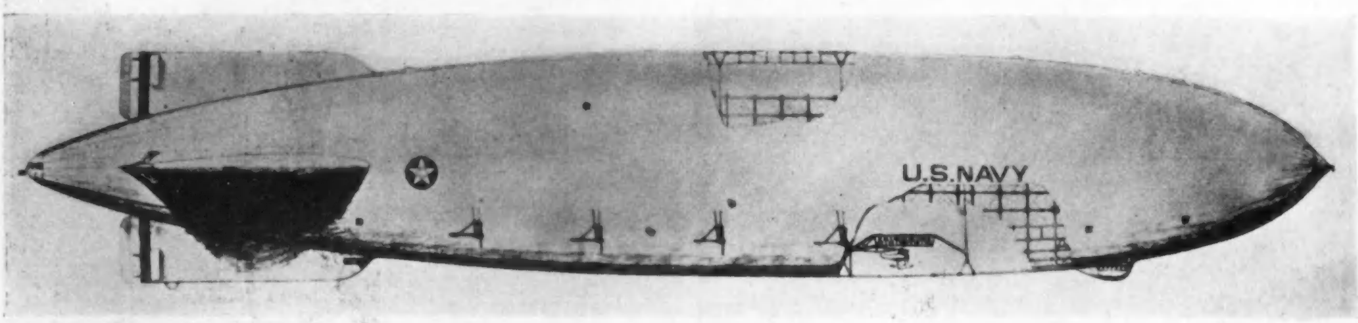


FIG. 8—GENERAL DESIGN OF NAVY HELIUM AIRSHIP, SHOWING PROVISION FOR CARRYING AIRPLANES

In the Broken-Away Portion Below, Aft of the Control Car, Is a 75 x 60 Ft. Compartment for Housing Five Airplanes. Through a T-Shaped Opening in the Floor, Covered by Collapsible Doors, an Airplane Can Be Lowered from and Hoisted into the Ship by Means of a Trapeze

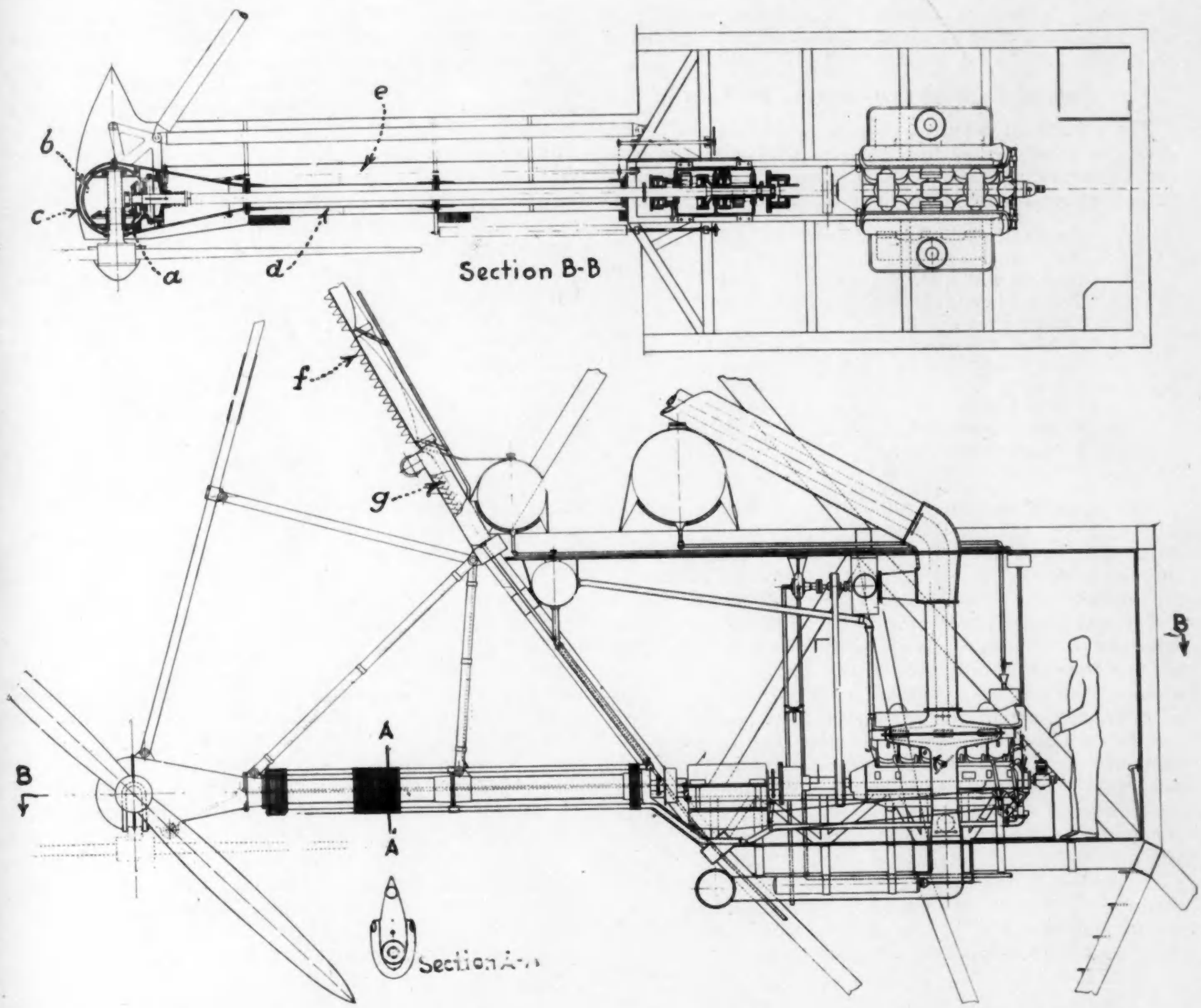


FIG. 9—ONE OF THE EIGHT POWERPLANTS AND SWIVELING PROPELLERS PROPOSED FOR THE PROJECTED LARGE AMERICAN AIRSHIPS

Directly Reversible Engines Are Installed in Separate Engine-Rooms Inside the Hull and Connected Through Rigid Driveshafts and Bevel Gears (*a*) to the Propellers. Thus, the Propellers Can Be Used for Both Forward and Reverse Drive and, by Tilting Their Axes Through 90 Deg., also for Vertical Thrust. The Swiveling Device Is Mounted in an Inner Spherical Case (*b*) Inside an Outer Case (*c*) Which Is Rigidly Attached to the Hull by a Braced Outrigger (*d*). The Inner Case Can Be Turned Through a Quarter of a Circle by a Worm Driven by a Rod (*e*) Extending into the Engine-Room, and Carries the Propeller with It. A Locking Clutch Engaging the Inner Housing Holds the Propeller-Shaft in Any Position. The Line-Shaft Can Be Disengaged from the Engine To Slow Down the Propeller Before Changing Its Direction of Thrust. A Proposed System of Water Recovery To Counterbalance the Loss of Weight from Liquid-Fuel Consumption Includes an Exhaust-Gas Pre-Cooler. Longitudinally Ribbed Condensers (*f*) Extending up the Side of the Ship, and Water Separators (*g*) Below the Condensers

also provide excellent means for ventilation of the ship.

Although no wire bracing is necessary for stiffening the rings, a netting of diagonal wires attached at every alternate corner to the inner annular ring is constructed solely to hold the gas cells in place. No additional cord netting is necessary, as would be the case with radial wire netting. The knots are designed to be perfectly smooth so that they cannot catch in or chafe the cell fabric.

The bulkhead will be designed to satisfy two seemingly contradictory requirements. In case of deflation of a cell, it is desirable to have the bulkhead bulge enough to keep the radial loads due to the bulkhead stress within reasonable limits. On the other hand, with adjacent cells equally inflated and the ship merely pitching, the bulging of the bulkhead should be accompanied by as little surging of buoyant gas as possible, so as to minimize or even avoid static instability of trim at all angles of pitch.

One of the most novel and picturesque features of the design of the Navy airships is the provisions made for the storage of five completely assembled airplanes. A storage compartment, about 75 ft. long by 60 ft. wide, is located about one-third of the ship's length from the

bow, as shown in the cutaway part of Fig. 8. Collapsible doors in the floor cover a T-shaped opening through which a trapeze with an airplane attached can be hoisted or lowered.

General Data of 6,500,000-Cu. Ft. Ship

The structural features of such a ship as this could easily be incorporated into a commercial mail and passenger-carrying airship. The general data for a 6,500,000-cu. ft. passenger ship would be as follows:

Over-all length, ft.	785
Maximum diameter, ft.	133
Over-all width, ft.	138
Over-all height, ft.	147
Fineness ratio	5.9
Nominal gas capacity, cu. ft.	6,500,000
Dead weight, lb.	210,000
Total lift, lb.	403,000
Useful lift, lb.	193,000
Maximum power, hp.	4,800
Maximum speed, m.p.h.	87
Cruising speed, m.p.h.	75

The range of the ship, while carrying 40 passengers, 20,000 lb. of mail and express freight in addition to 55 members of the crew, would be about 4700 miles at top speed, 6100 miles at a cruising speed of 75 m.p.h., and 10,000 miles at a cruising speed of 60 m.p.h.

Too much emphasis cannot be given to the structural strength of this ship, which is considerably in excess of that found in previous ships. The proposed commercial ship has been designed with sufficient strength to meet such conditions as: (*a*) violent maneuvers of the rudders and elevators, both alone and in combination; (b) flying at excessive angles of pitch due either to surplus buoyancy or to using the maximum available dynamic lift; (*c*) ship flying at full speed into a perpendicular gust region having a speed of 60 ft. per sec. and a sharp border line.

In the design, the first two conditions were relatively easily met. The third, or gust, condition was the most severe, but was met by the design with a theoretical structural factor-of-safety greater than 2. The research connected with this third condition was of considerable interest. The problem was approached mathematically by computing the air forces and their free moments in any phase of entrance of the ship's forebody into a vectorially defined cross-wind zone. The resulting simultaneous differential equations of motion were integrated and the inertial forces corresponding to the ensuing motion with which the ship responds to the gust were evaluated. With these, the bending moments and shearing forces exerted upon the different cross-sections at various times after entry into the gust zone were computed and their maxima determined with respect to location and time of occurrence.

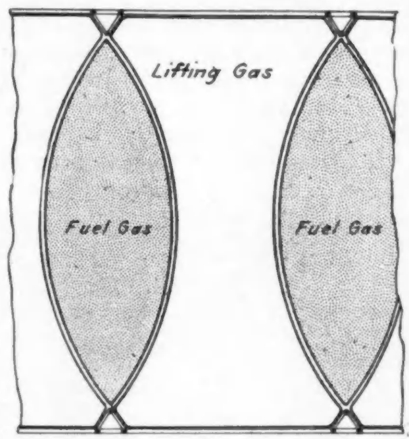


FIG. 10—POSSIBLE ADVANTAGEOUS GAS-CELL ARRANGEMENT FOR SHIPS WITHOUT WIRE BRACING AND USING HELIUM FOR BUOYANCY

The whole investigation was carried out for different assumptions as to the method of steering. Two cases are of specific interest; one in which the helmsman attempts to keep the ship true to its compass course, and the other in which he refrains from any sudden interference with the ship's tendency to veer. The sharp-bordered gust of 60 ft. per sec. is a very severe assumption. Meteorological investigations show that gusts are not bounded by mathematically sharp borders, but are surrounded by transition zones in which a finite velocity-gradient exists. In actual flight a considerable portion of the ship's body enters into the disturbance zone before the nose experiences the maximum gust velocity. It is evident that a ship designed to withstand an imaginary sharp-bordered gust will therefore be safe in actual gusts of a considerably greater final velocity.

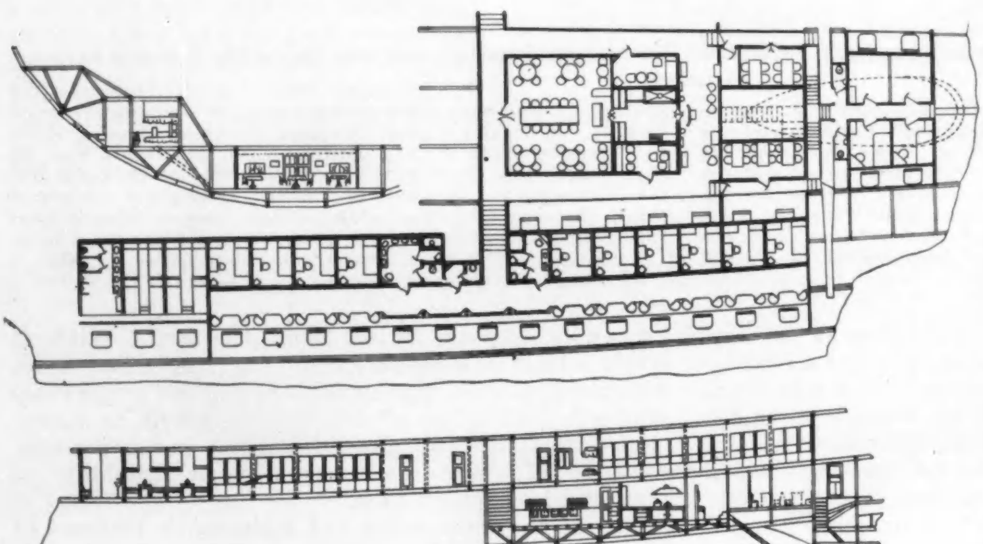


FIG. 11—PROPOSED ARRANGEMENT OF PASSENGER ACCOMMODATIONS INSIDE THE HULL OF HELIUM-INFLATED AIRSHIP

Powerplant Location and Drive System

Another feature of the ship is the location of the powerplants and the consequent adoption of a new and improved drive system. The eight directly reversible engines are installed in separate engine-rooms inside the hull and are connected to rigid driveshafts which extend outside of the hull to the propellers. The use of bevel gears makes it possible to use the propellers, not only for forward motion and reversing maneuvers, but also for vertical thrust by tilting their

axes 90 deg. This feature will be of great importance in starting and landing maneuvers. It will also enable the carrying of more payload and avoid the loss of lifting gas when the ship has to be landed against surplus lift.

The general layout for the swiveling propellers is shown in Fig. 9. The device is mounted in two cases, the outer of which is attached immovably to the ship by means of a braced outrigger. A worm wheel is attached to the inner casing. By operating a worm, driven by an extension rod reaching into the hull, the whole inner casing, and with it the propeller, can be swung through an angle of 90 deg. The propeller is held in any position by a locking clutch which engages with the inner housing. Since the engines are directly reversible, the 90-deg. swing of the propellers makes the delivery of thrust possible throughout a complete range of 360 deg. A clutch is provided within the hull, so that the line-shaft can be disengaged from the engine, as it is advantageous to slow the propeller down considerably before changing its direction of thrust.

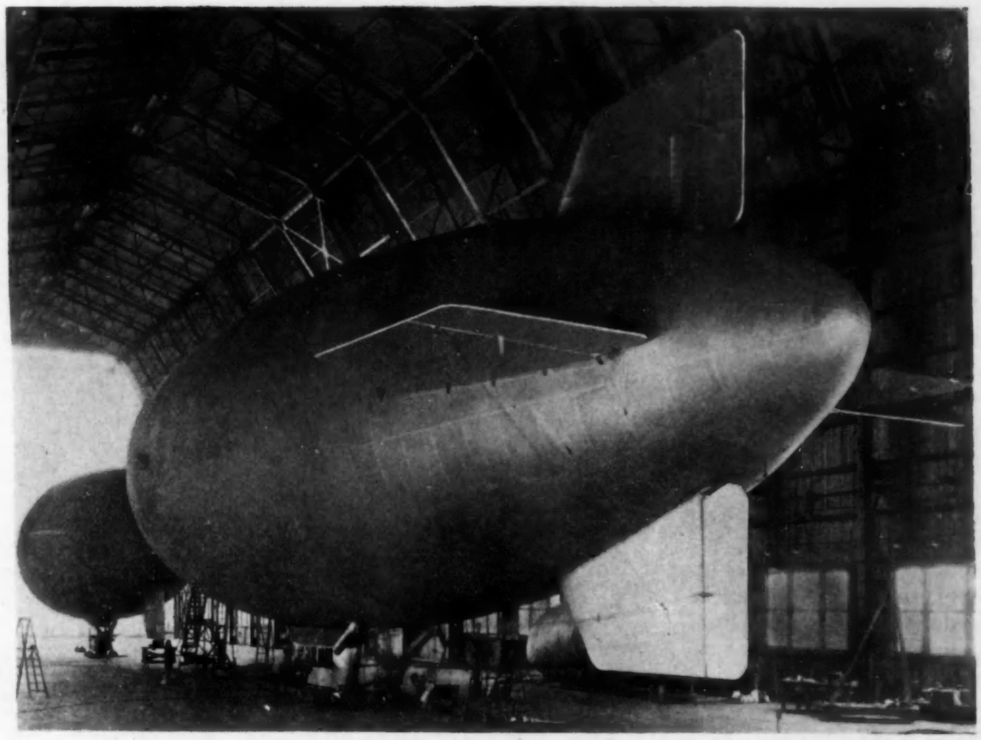


Fig. 13—The Pilgrim and the Puritan Non-Rigid Passenger-Airships

Water Recovery from Fuel Combustion

If liquid fuel is used for propulsion of the ship, a definite loss in weight is experienced which would ordinarily require the release of a corresponding quantity of the lifting gas. Attempts have been made to compensate for the loss of weight by various methods, the most successful of which was developed by the Navy Department. This utilizes engine-exhaust condensers consisting of a system of connected tubes exposed to the airstream and installed between the engine car and the hull. This device has proved satisfactory as to thermal effect, but involves considerable parasite resistance.

We have investigated the possibility of eliminating considerable of this parasite resistance by locating the condensers along the surface of the hull. The system as proposed is equipped with a counterflow pre-cooler that takes the exhaust gases directly from the engines and drops their temperature about 80 per cent. After taking up the heat, the air used as a cooling medium is piped away to be used for heating the control car and passenger quarters. From the pre-cooler the gases pass into the condensers. These are large, metallic panels which extend from the engines up the sides of the ship. Their outer surface is ribbed longitudinally, the ribs projecting into the airstream so as to provide the maximum cooling effect with the minimum resistance. Water separators are located at the bottom of the condensers, and the water recovered can be piped from them to the ballast bags.

This buoyancy difficulty may also be solved by the employment of a natural gas somewhat lighter than air as a fuel in addition to a certain amount of gasoline or other liquid fuel. Consumption of the gas causes the ship to become gradually heavier, while the use of the liquid fuel lightens the ship. The commander thus has at his disposal a means of regulating the buoyancy of his

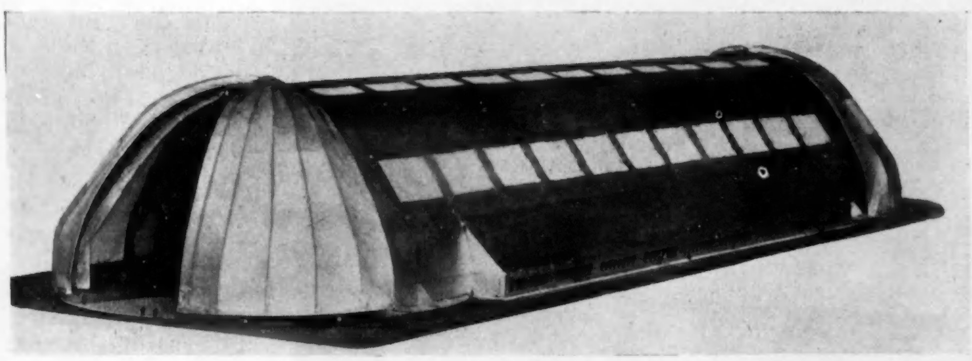


Fig. 12—Model of Airship Dock for Construction of Two Navy 6,500,000-Cu. Ft. Airships

Erection of an Airship Factory and Dock of This Design Is Under Way on the Municipal Flying-Field at Akron, Ohio. The Structure Will Be 1200 x 325 x 200 Ft. in Size and Provided with Rolling Doors of the Design Shown. The Entire Structure Is Well Rounded to Avoid Local Regions of Extreme Wind-Pressure Variations and Give a Smooth Airflow Over It

ship to meet various conditions of temperature and precipitation. He has merely to use the two fuels simultaneously or alternately to maintain complete control of equilibrium and trim, thus dispensing with an elaborate system of water recovery.

Special Solution of Fuel-Gas Storage

The combination of built-up rings, elastic bulkheads, and helium inflation, which we plan for our commercial liners, makes possible a special solution of the fuel-gas carrying problem, as illustrated in Fig. 10. Fuel-gas cells are built into the ship between any two adjacent helium cells. Their outer edge is attached to the inner annular ring completely around the ship, while the sides of the cells are restrained by the bulkheads. Such an arrangement provides reasonably safe storage of the fuel gas, accessibility completely around the ring, and reduces the liability of impurifying the lifting gas, due to the fact that there are two thicknesses of cell fabric between the two gases.

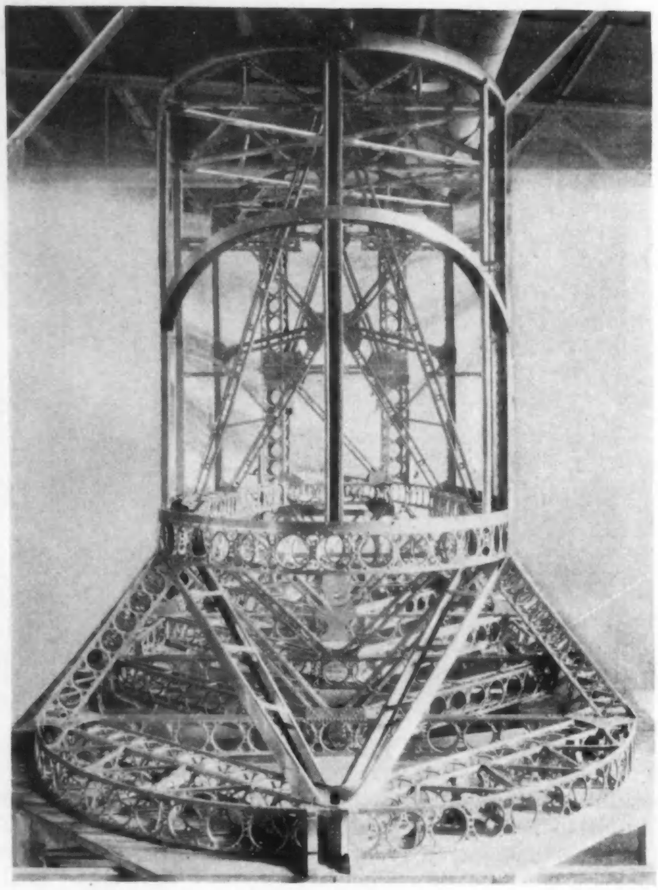


Fig. 14—Car of the Puritan Under Construction, Shown from the Front and Inverted

Other reasons also favor the use of fuel gas on commercial ships. It is safer with regard to fire hazard, because the natural gas, which is rather less explosive than gasoline fumes, can be surrounded easily and entirely by the non-inflammable helium. Only a small quantity of gasoline would be necessary, and even this might be eliminated in the future by the substitution of fuel oil. Fuel gas has the additional advantage of increasing the service ceiling of the helium ship, from which the lifting gas cannot be wasted. At the start, the ceiling is limited by air space available inside the hull for the expansion of the gas as the ship gains altitude. When the ceiling is reached, the gas cells completely fill the hull. Combustion of the fuel gas gradually increases the available space for lifting-gas expansion. The fuel-gas ship will therefore be able to obtain a higher ceiling with less loss of pay-load than a similar type of ship using liquid fuel and water-recovery apparatus. This increase in ceiling is very valuable where mountains have to be crossed. It also provides a means of climbing over storms and surface disturbances. This latter feature is of great value in commercial service, in which safety and reliability are very important.

Our greatest problem in commercial operation is mooring and ground handling. The Navy has realized the importance of the problem and is now conducting valuable experiments in decreasing the man-power used for these operations. During the last few years it has devoted attention to developing stub and portable masts. It seems that the solution of the problem is in the nature of a mobile telescopic mooring-mast that can be raised or lowered to receive the ship from the air and moor it near the ground, and even be used for hauling the ship into the hangar.

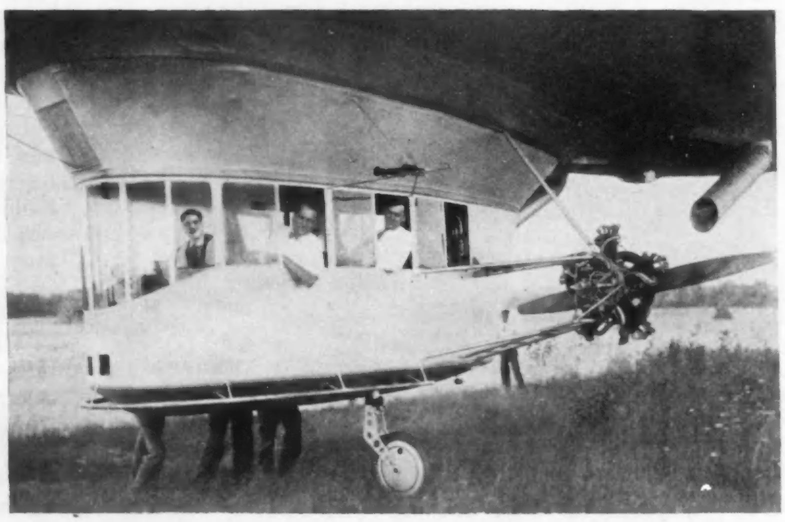


Fig. 15—Completed Car Supported from the Gas Bag of the Puritan, Showing One of the Two 70-Hp. Radial Air-Cooled Engines with Its Propeller

Passenger Accommodations Inside the Hull

Accommodations provided for travelers in the proposed ship are of considerable importance and interest. The floor plan in Fig. 11 will give some idea as to their comfort and roominess. The use of hydrogen as a lifting gas has demanded, for safety against fire hazard, that the passenger accommodations in airships built up to the present time be placed in a car outside of the main structure. All

such protrusions must be reduced to the minimum to avoid decrease of speed, with the result that passenger accommodations have been much restricted. On military or naval airships, relatively little allowance of weight or space was made for the comfort of passengers.

American-built commercial air-liners possess a tremendous advantage in that this Country has a monopoly on helium. It is the privilege of our organization to build ships using this non-inflammable gas and thus to be able to incorporate new features of safety and comfort into the airship art. Passenger compartments are retracted into the hull, with the result that passenger accommodations may be extended almost at will, while aerodynamic efficiency is considerably increased. Promenade decks, libraries, lounges and smoking-rooms are no longer dreams but are actualities.

The same considerations apply to the power cars. In hydrogen ships the engines must be carried in small gondolas suspended outside of the hull, where they have good ventilation and minimize the fire danger. Their exposure to the airflow makes it necessary to limit their size as much as possible. In the helium ship, the engines can readily be housed inside the hull, thereby further saving parasite resistance and gaining propulsive efficiency in addition to improved accessibility of the engines.

British 5,000,000-Cu. Ft. Hydrogen Ships

British aeronautic engineers have not been idle. They now have under construction two long-distance passenger and mail air-liners. They have fixed upon 5,000,000-cu. ft. hydrogen ships as the most suitable size for the establishment of their lines. This is of the same order of magnitude as our projected helium passenger ship, as far as lift is concerned.

The two British ships are of a somewhat experimental nature, especially as regards structure. The British have reduced the number of longitudinal members employed to less than half the number advocated in present practice. This gives tremendous areas of outer cover which must be supported against the air forces by auxiliary means. Compared with our proposed ship, the British ships are slower by several miles per hour. They have accommodations for more passengers, but range and freight space have been sacrificed for passenger-carrying ability. Furthermore, according to information now available, they are not expected to be able to carry a full complement of passengers except on the short eastern flight from Montreal to England. Construction of the ships is proceeding rapidly, and they are expected to be completed in the summer of 1929.

In keeping with the progress of the construction of rigid airships, development of harboring facilities for them has extended all over the world. Docks and mooring masts have been and are being built in Argentina, Australia, Canada, Egypt, Germany, Norway, India and Spain.

World's Largest Airship Dock

Erection of the world's largest airship factory and dock upon the municipal flying-field at Akron, Ohio, has been begun by the Goodyear-Zeppelin Corp. The dock is 1200 ft. long, 325 ft. wide, and about 200 ft. high. It is well rounded in form and equipped with doors of a special spherical calotte design, as shown by the model reproduced in Fig. 12. The avoidance of sharp corners eliminates local regions having extreme air-pressure variations, while the airflow over the whole structure is unusually smooth.

Elaborate wind-tunnel tests of a model of the structure were conducted at the Guggenheim School of Aeronautics at New York University, and wind pressures were recorded at more than 200 orifices arranged at strategic points on the surface. Experiments were conducted with the wind approaching from all angles and with the doors in every conceivable position. Interesting results were obtained with respect to ventilation. The wind forces and their distribution over such a building were found to be in agreement to a large extent with theoretical anticipation. Knowledge on the subject, however, was considerably extended. The aerodynamic advantages of a rounded structure with flush revolving doors were convincingly demonstrated in respect to the safety and structural economy of the building, as well as the avoidance of aerodynamic disturbances which are disagreeable hazards to the ground-handling of the airship.

Construction of Small Non-Rigid Ships

The aeronautical department of the Goodyear Tire & Rubber Co. has been building and operating airships since 1912; and now the Goodyear-Zeppelin Corp. is engaged in the construction of a fleet of small non-rigid airships. Commercial aeronautic activities have been undertaken with two non-rigid airships, the Pilgrim and the Puritan, shown in Fig. 13. The Pilgrim, built as a pioneering ship, has a gas capacity of only 50,000 cu. ft. It has been used for passenger carrying, publicity and advertising, research tests, student instruction, and general aeronautical promotion work. It was the first American non-rigid airship to use an internal suspension system. The car is hung beneath a central keel girder, about 20 ft. long, laced to the outside of the gas bag. The keel is supported from within by cables which pass up through the bag and terminate in catenary cables running along the top of the bag. As the whole suspension is internal, it was possible to neatly fair the car into the envelope, thus completely eliminating the drag of the car-suspension cables.

The Pilgrim is driven by a 60-hp. engine mounted at the rear of the cabin, and attains a speed of 45 m.p.h. when carrying a pilot and two passengers. Since its erection, the ship has made 533 flights, a great number of which have been training flights. In addition to this, some 300 passengers have been carried.

The Puritan is a larger ship, of more recent design and incorporating several improvements. The central keel girder of the Pilgrim has been developed into a box-girder frame of the same shape as the car but larger and built into the upper car-structure, as shown under construction in inverted position in Fig. 14. A system of short catenary loops arranged around this structure serves to transmit the longitudinal and horizontal components of the car's weight and thrust to a large area of the lower surface of the gas bag. The vertical loads are transmitted directly to the top of the bag by a system of cables and pulleys connecting the ends of the keel with the top of the bag, whence the load is distributed by means of two separate catenary curtains extending fore and aft. Fig. 15 shows the completed car, suspended from the gas bag, and the port engine and propeller.

(*Concluded on p.* 487)

Spinning Characteristics of Airplanes

By Dr. Michael Watter[1]

Metropolitan Section Aeronautic Division Paper

THE causes and nature of the spinning of an airplane, and measures for the prevention of and recovery from a spin, are discussed. Tests and analysis are said to have shown that spinning is a stable motion of rotation, and that the real dangers are in its instability. Recovery from a spin is held to be more important than prevention, as complete knowledge of means of recovery will lead to mastery of the whole phenomenon.

The spinning motion is a combination and balance of aerodynamic and purely dynamic forces and couples, asserts the author. Full-scale experiments prove beyond doubt that side-slip may be very pronounced in a spin, which changes considerably the rate of roll of the simple autorotational kind. The rolling of the wings leads to a yawning couple which may become dangerous, tending to keep the craft in a spin because of the increased shielding of the tail surfaces.

The dangerous spinning tendencies of modern airplanes are stated to be due primarily to the trend of design toward high speed, heavy loading per square foot of wing area, short and deep fuselages, and consequent shielding of the tail surfaces at the high angles of attack associated with spinning.

Some new disposition of the control surfaces so as to increase their effectiveness and particularly to prevent shielding of the rudder by the body is more important, the author believes, than increase in the size of the stabilizing and control surfaces.

Conceding that automatic front wing-slots prevent the possibility of an incipient spin and are a positive means of recovery from a normal spin, doubt is expressed of their successful use in recovery from a flat spin. It is suggested that it would be interesting to investigate the possibility of using automatic leading-edge slots on the horizontal tail-surfaces.

In conclusion, four characteristics of paramount importance in preventing an incipient spin are given, and five characteristics for assuring recovery are enumerated as desirable.

SPINNING of an airplane was first mentioned in the Wright brothers' patent, dating back to March 23, 1903. The heights attained at that time were insufficient really to spin, but the circumstances described in the patent leave no doubt as to the character of the phenomenon. Ever since, with the progress of flying, the toll of life taken by spinning has mounted, and there came a realization of the dangers associated with it.

At first, spinning was thought of as a certain unstable motion from which no recovery was possible; but, in the light of tests and analysis, it was found that spinning presented a stable motion of rotation and that the real dangers are in its stability. It was also found that recovery required a certain movement of control and a considerable loss of altitude, which explained a number of accidents. Further and more recent investigations and tests disclosed that the phenomenon of spinning is still more complicated because of the individual behavior of various airplanes and the different kinds of observed spins.

Spinning is of special interest to designers of military aircraft because it is regarded by many as a desirable and valuable maneuver in combat. This viewpoint is not held by all the experts; some contend that spinning has little, if any, military value and should be abandoned as a maneuver. Whether it is or is not of value in military combat, as long as spinning is possible, the aim of designers is to understand it thoroughly and to give pilots definite means of recovery from the spin.

I mention recovery and not prevention because, when the plane is in the spin, the dangers involved are real and immediate, and complete knowledge of this phase of behavior will lead to the mastery of the whole phenomenon. Prevention means control at low speed, and it seems logical to assume that, when means of recovery are found, they may in themselves provide powerful means for preventing spinning.

Autorotation of Airfoils

It was, and unfortunately still is, almost a general belief that the spinning of airplanes can be explained and accounted for solely by the autorotational properties of the wing or the wing cell used. To trace the possible connection of these two phenomena, it is well to review the autorotation which, I believe, was first observed and studied in 1906 by the Russian scientist Riabushinsky in the Aerodynamical Institute of Koutchino.

Autorotation is a property of symmetrical bodies invested by a relative wind to autorotate when once given an initial rotation. It would be natural to explain this property by pointing out the impossibility of building a perfectly symmetrical body; but this hypothesis can be disproved by causing such bodies to autorotate in either direction, depending on the direction of initial rotation. An experiment of this type can be made with a rectangular piece of cardboard, which, if released and allowed to drop without an initial rotation, will descend almost vertically; whereas, if given an initial rotation about its longer side, it will descend spinning and its trajectory will be noticeably inclined. I suggest this elementary experiment because, in analyzing spinning, too much attention is being paid to the wing combination, when, as a matter of fact, any part of the airplane may and does contribute to the spinning.

In analyzing wing behavior, it was found that a wing mounted symmetrically in the wind-tunnel on an axis along the wind (see Fig. 1) soon after the angle of stall is passed, has an autorotational tendency which,

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prior to that at angles below the stalling, is damped by the air reaction. After the angle of attack has been increased to about 30 deg., the autorotation can be caused only by a certain comparatively great initial rotation. At angles of attack greater than about 40 deg., the airfoil reverts to the same behavior noted below stalling angles. The region immediately after the stalling angle is called the region of spontaneous autorotation, while the second is the region of latent autorotation.

In the case of a biplane arrangement, the first region retains its character, while the second becomes a function of the cell arrangements. In the case of positive stagger, the cell behaves somewhat as a monoplane, while in case of zero or negative stagger, the second region may also become spontaneous and remain so up to very large angles of attack.

The explanation of the phenomenon of the autorotation of airfoils can be readily obtained by analyzing the change in the angle of attack of the two sides of a rotating airfoil in reference to the relative wind and by observing the variation in the air reaction on the airfoil. This analysis can best be made using the polar diagram of the wing (Fig. 2) as suggested by Montgomery Knight, of the National Advisory Committee of Aeronautics, in his report on Wind-Tunnel Tests on Autorotation and the Flat Spin. The direction of the relative wind must be obtained by combining, according to the laws of mechanics, the velocity of the airstream and the velocity of rotation. On the side of the airfoil where, owing to rotation, the under camber is, so to say, cutting the airstream, the angle of attack is increased, while on the opposite side it is decreased. From the polar diagram, it will readily be observed that, for certain angles of attack beyond the angle of maximum lift, this would correspond to a decrease in the air reaction on the former elements of the airfoil and to an increase on the latter elements, the air forces thus maintaining the initial rotation of the airfoil.

Spinning of Airplanes

In analyzing the spinning of airplanes, it is well to remember that spinning can occur under such a variety of circumstances and attitudes, which in themselves may differ widely in different airplanes, that no such thing as "the spin" should be considered, but the problem should be viewed with more latitude.

In a normal spin the center of gravity of an airplane describes a helical trajectory with a radius equal approximately to the semi-span, and the general attitude is that of being well down by the nose. This attitude usually impresses a layman as if the plane were diving along a steep spiral path, but a simple observation will easily disprove this impression. It is sufficient to note the relatively slow speed of descent of the spinning craft to realize that the airplane is in an attitude presenting a very high drag, and that the effective angle of attack, that is, the angle of attack in relation to the relative wind, is consequently very high. A mathematical analysis could easily prove that the airplane has passed its stalling angle, and the angle of attack is usually about 30 to 40 deg.

As the visible inclination of the body decreases, the rate of rotation increases, the effective angle of attack increases, and the plane enters into regions of "flat" spin with a radius of helix of only a few feet. The transition from a normal spin to a flat spin is rather hard to describe, and the difference between these two kinds of spin usually is assumed only in the relative inclination of the body. (See Fig. 3.)

It was formerly supposed that the dangers of non-recovery are present in the case of flat spins only. Recently, a number of cases have been reported in which the spinning of the airplane occurred with an attitude of the body down by the nose and non-uniform rotation was accompanied by jerks. These kinds of spin are called "peculiar spins," but information available so far is rather meager, and beyond the fact of their dangerous character very little is known on the subject. The rate of rotation observed is usually very high, and several cases of non-recovery were reported for this type of spin. It may be said in general that, irrespective of the character of the spin, as long as the spinning characteristics of the particular airplane are unknown it is well to regard any spin as dangerous and attempt to recover as soon as possible.

The fact that in a spin the axis of rotation is nearly coincident with the direction of velocity suggests that the autorotation of the cell is the main contributing cause of this type of motion. This viewpoint is held by many, but it is my belief that, although the rolling couple may contribute to the entrant motion, its effect in an established steady spin may be considerably smaller than the effect of the complete unit of wings, body and tail surfaces. The autorotational properties of the cell may be one factor in the spinning characteristics of an airplane, but an airplane may not display any steady spinning tendencies with a cell having autorotational tendency. In fact, it may display it with a cell not having any pronounced autorotational couple, such as a monoplane, depending on the mass distribution and the disposition of stabilizing and controlling surfaces. The spinning motion is a combination and balance of aerodynamic and purely dynamic forces and couples, and simple aerodynamic tendency is but one factor in it.

Sideslip may be very pronounced in a spin, in which case the rolling due to sideslip will greatly influence the rate of roll of the simple autorotational kind.

Study of the geometry of spinning may lead one to doubt the presence of sideslip or to attribute to it only secondary significance. Full-scale experiments, however, prove beyond doubt the presence in many cases of a large amount of sideslip, which cannot be neglected in a detailed analysis of spinning. Quoting from Reports and Memoranda 1001, of the Advisory Committee for Aeronautics (British) by Messrs. Gates and Bryant:

> . . . the final appeal in this matter is to a full-scale experiment in which a large sideslip is observed beyond a vestige of doubt. . . . Thus, it is dangerous to assume anything more than a very loose connection between autorotation and the equilibrium conditions in a spin.

The rolling of the wing or cell leads to a yawing couple, which may or may not be of the same sense as that due to the body and tail surfaces. It appears that, up to an angle of attack of about 30 to 40 deg., the magnitude of the yawing couple due to the body and tail unit predominates and the resultant yawing of the airplane is opposite to the yawing of the wings. Above these angles the shielding of the tail surfaces becomes more pronounced, and consequently the effect of the yawing moment becomes more dangerous, tending to keep the craft in the spin despite a probable yawing couple due to the body's tendency to check it.

In addition to rolling and yawing couples, there are also present pitching couples, of which one, normal to the high-incidence condition, has a tendency to depress the nose of the airplane. The damping couple due to the component angular velocity in pitch may, however, have a tendency to raise the nose, as apparently occurs in fast spins.

Dynamic Aspects of Spinning

The problem of spinning differs from simple autorotation not only in its aerodynamic aspects but to a considerably larger degree by the effect of purely dynamic couples.

In studying the phenomenon of autorotation in a wind-tunnel, the stalled attitude of a wing, cell or model is obtained by means of rigid supports. In case of a spinning airplane, no such supports are present. Since, however, the stalled attitude of the craft is a necessary condition for autorotation, what maintains the high angle of attack of the spinning airplane, often despite the best efforts of the pilot to lower the nose?

The explanation lies in the presence and magnitude of the precessional pitching moment. Since the axis of rotation in spinning does not coincide with any of the three principal axes of the airplane, three gyroscopic moments are set up which are functions of the components of the angular velocity and moments of inertia. The relative magnitude of the moments of inertia is of the utmost importance in spinning, because it is the combined effect of aerodynamic and dynamic couples that determines the attitude of the airplane.

In dealing with the problem of gyroscopic moments, it is important to consider the effect of a rotating propeller. The gyroscopic action of the present heavy metal propeller rotating at a considerable angular velocity is important even when the propeller is idling, and is of great magnitude when the pilot attempts to recover from a spin by putting on the power. Depending on the sense of rotation, the propeller may have a gyroscopic action tending to raise the nose of the craft still more, thus increasing the rate of rotation of the airplane. When the sense of rotation of the airplane and the propeller is opposite, the switching on of the power will cause an undesirable pitching moment leading to a flatter and faster spin. This point is of great importance and may be the explanation of a number of accidents.

Entry and Recovery

Entry into the spin can be subdivided into voluntary and involuntary, depending on whether the pilot intends to execute a spin or must face it as a consequence of peculiar behavior of his craft under certain conditions.

The main necessary condition for a spin is the stalled attitude of the airplane. Involuntary spin may occur when flying at nearly stalled attitude in attempting to execute a turn; the yawing moment due to the normal ailerons and passing of the burble point on the side which is raised may cause the spin. A similar case may occur when climbing; a sudden stopping of the engine which causes loss of speed while the plane has a very high angle of attack will result in rolling instability and a spin. The latter case precludes the possibility of correcting the spin by decreasing the power of elevator. Voluntary entry is made by pulling the stick back to attain the stalled attitude and then applying the rudder and ailerons or either of the two. The control movement is the direct consequence of the aerodynamic behavior of the airplane; first it is brought to the attitude of rolling instability and then caused to rotate by application of either or both the lateral and directional controls.

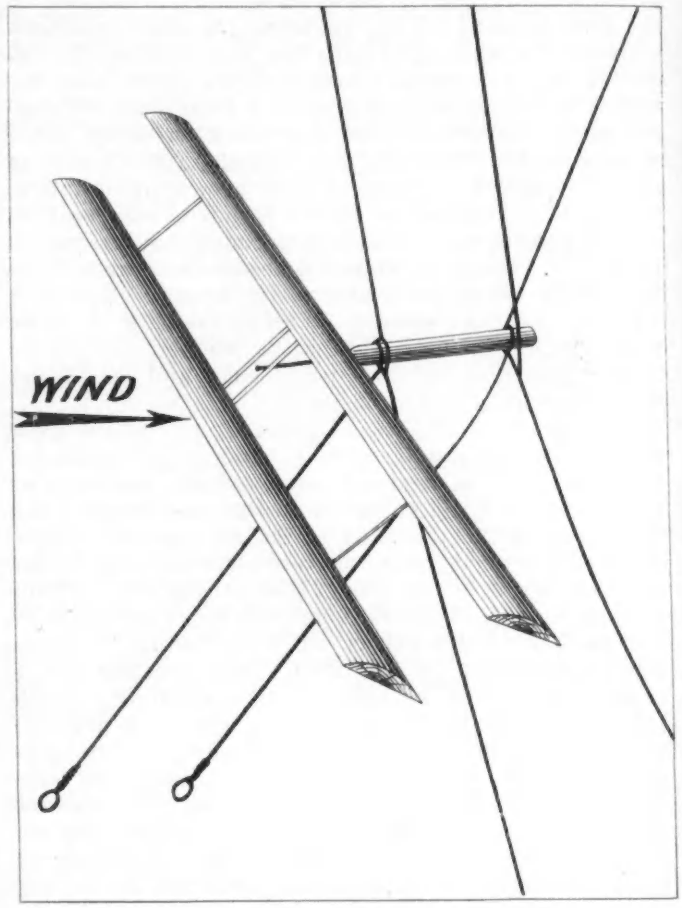

FIG. 1—MODEL MOUNTED IN WIND-TUNNEL FOR STUDYING AUTOROTATIONAL TENDENCY

Recovery is attained by returning to the pre-stalled attitude and stopping the rotation. To do this, the pilot pushes the stick forward so as to lower the nose of the airplane and then neutralizes or reverses the rudder. If the sense of rotation of the airplane is the same as that of the propeller, he may put the power on to expedite recovery, but I believe it is better to refrain from using the power, as the pilot is likely to confuse the sense of rotation.

While spinning, if the pilot feels a sudden reverse of load on the control stick, that is, if the stick is being kept back by the air force on the elevator, he must regard this as a danger sign indicating a change into the region of highly stalled flat spin, and he must immediately attempt recovery. The controls should not be "pumped," and the pilot must bear in mind that in modern airplanes the altitude required for full recovery may be as much as 2000 ft.

Effect of Controls

Because of the highly stalled attitude of the airplane in a spin and of the low speed of advance, the action of control surfaces is very ineffective. This is particularly true in reference to the stabilizer and the elevators. The inefficiency of the rudder results mainly

from the shielding effect and the interference due to the body and the horizontal tail-surfaces. The action of the ailerons does not seem to have been sufficiently studied and, in general, pilots have attached very little significance to their effect. In entering the spin, the ailerons contribute a large rolling moment; but once in a spin, with high angles of attack, the pilot usually feels that their effect is negligible. Whether this is true cannot be decided without further data, for it is very probable that during a spin aileron action is confused by many pilots with that of other controls. It has been observed that, in reversing the ailerons so as to oppose the spin, the rate of rotation is not only undiminished but sometimes is increased.

In attempting to evaluate the effectiveness of various controls, it is necessary to view the problem of spinning in all its complexity. The action of controls must be considered in its relation to aerodynamic and dynamic forces and couples acting on the airplane; and, because of individual characteristics of different airplanes and types of spin, the effect of various controls cannot be generalized. Since the dangers of spinning are in the stability of the motion, it may be sufficient to change only one condition in order to stop the spin. The airplane can be brought out of the spin (*a*) by means of longitudinal control, by forcing it out of the regions of past-stalled attitude; (*b*) it can be stopped autorotating if sufficiently powerful lateral control is available; or (*c*) recovery may be made by means of the rudder, by opposing the undesirable aerodynamic and dynamic yawing moments. The effect of the various controls may be different in different airplanes and may

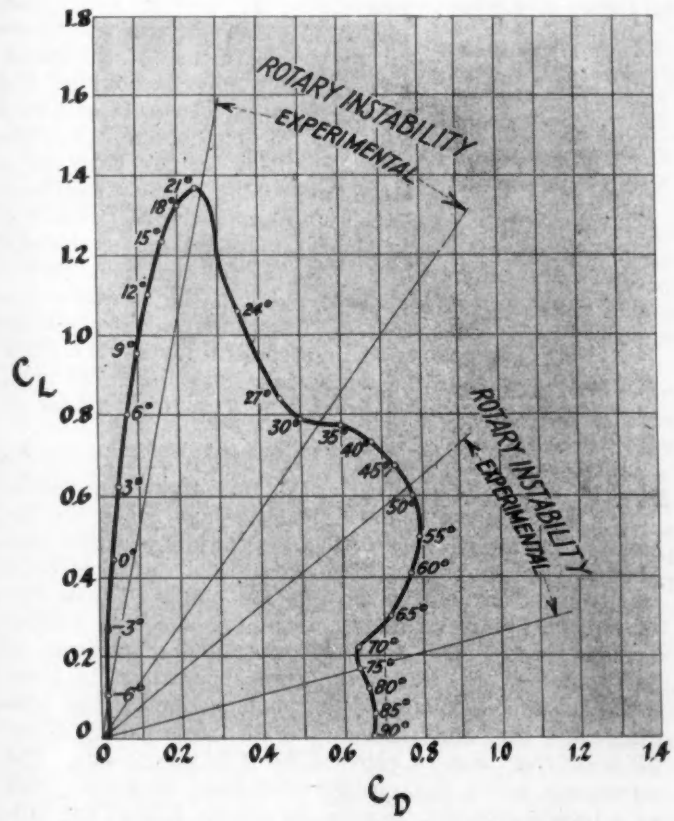

FIG. 2—POLAR DIAGRAM FOR 5X30-IN. BIPLANE CELL
$G/c=1$, Stagger$=0$, $q=20.2$ Kg/M², Reynolds Number$=156{,}000$

not be alike for the same plane for various spinning attitudes. Also, various combinations of control movements may lead to different results.

Location of Center of Gravity

Location of the center of gravity cannot, of itself, affect appreciably the moments of inertia of the airplane, but it does affect the condition of longitudinal balance. With the center of gravity located far back, the horizontal tail-surfaces will be trimmed so that their effectiveness will be considerably decreased at high angles of attack. Also, the resulting change in pitching moments will lead to a different condition of equilibrium of aerodynamic and dynamic couples.

It is precisely in the loss of effectiveness of the horizontal tail and a different condition of balance that lies the undesirable effect of the rearward movement of the center of gravity. I believe, however, that for a location of the center of gravity such that the condition of longitudinal balance for normal flying conditions is not affected adversely, the relative position of the center of gravity has, in general, but little effect on the spinning characteristics of an airplane.

Dangers of Spinning

The dangers involved in spinning may be divided into four groups: (*a*) mechanical, (*b*) structural, (*c*) physiological, and (*d*) flying. Mechanical causes include the aerodynamic and dynamic behavior of the airplane.

(*a*) Certain airplanes that are hard to bring into the spin and have no tendency to fall into an incipient spin were found to behave dangerously once they were put in a spin. Such planes have a tendency to go into a flat spin, and the recovery in such a case is handicapped by insufficient power of control, which is necessary to counteract the dynamical stalling moment of the airplane. The centrifugal force is so great at times that certain cases of non-recovery may be due to the pilot's inability to push the stick forward.

(*b*) Structural dangers may be due to excessive stresses developed as a consequence of rolling moment and centrifugal forces. Other stresses are low, and the accelerations recorded do not exceed 3g.

(*c*) Physiological dangers are due to dizziness of the pilot resulting from continuous rotation of the airplane and consequent apparent rotation of the field of view. This rotation also influences the semicircular canals of the ear, thus affecting the pilot's sense of balance.

(*d*) Flying dangers consist in spinning at low altitude; putting the power on when the resulting gyroscopic moment tends to build up the incidence; not waiting until the controls become effective, but "pumping" them; and, finally, not realizing that recovery in a modern military plane may require the loss of 2000 to 3000 ft. of altitude.

The Mastery of Spinning

The mastery of spinning lies in a reliable means of recovery, not in the prevention of a spin. The problem is as much a problem of dynamics as of aerodynamics. The dangerous spinning tendencies of modern airplanes are primarily due to the general trend in design. High speeds attained with present airplanes necessitate a heavy loading per square foot of wing area, and the desire for high maneuverability ordinarily leads to shorter fuselages. The requirements of service, be it

military or commercial, necessitate a deep fuselage, with the consequent shielding of the tail surfaces at the high angles of attack associated with spinning. Aerodynamic arrangements of the wing cell have only a secondary influence in the persistency of spinning, although they do have a contributing effect in entry into spins. The center of gravity location is not of such importance as some may deem it.

The monoplane, which aerodynamically has no dangerous spinning tendency, may be dangerous in spinning because of the dynamic distribution of masses and probably also because of disposition of the control surfaces.

A modern American military plane having a highly staggered cell was spun in an attempt to prove the beneficial effect of stagger. It was fortunate that the proof was not carried too far and that the pilot had enough altitude to allow him to recover from the spin, for, in spite of the pronounced stagger, recovery was accomplished only with great difficulty. Another well-known plane, which spins normally as a landplane, spins even faster as a seaplane, despite a more forward location of the center of gravity in the latter. This is direct proof that the dynamic disposition of masses may be more important than the aerodynamic arrangement of the cell.

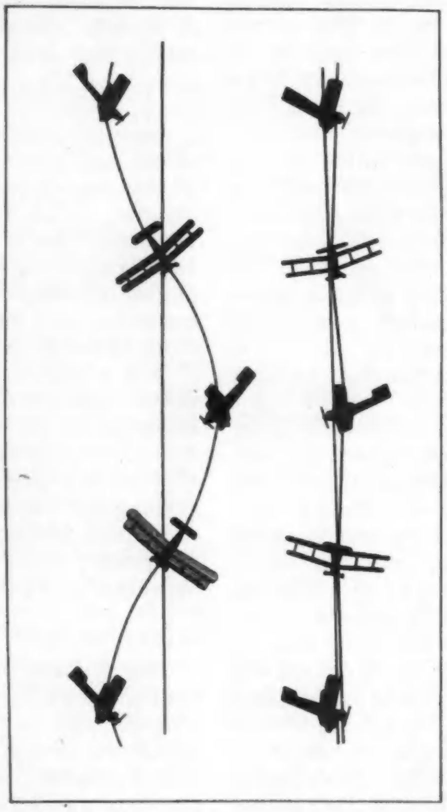

FIG. 3—AIRPLANE IN A NORMAL AND A FLAT SPIN

In a Normal Spin the Center of Gravity Describes a Helical Trajectory with a Radius Equal Approximately to the Semi-Span and the General Attitude Is Well Down by the Nose. In the Flat Spin the Radius of Helix Is Only a Few Feet, the Inclination of the Body Is Less, and the Effective Angle of Attack Is Increased

Another matter of importance is the disposition of control surfaces, which may lead to lack of control because of the mutual shielding of the surfaces and the effect of the body. Increase in size of stabilizing and controlling surfaces is only a temporary remedy, in my opinion; it would be much more desirable to study some new disposition of controls so as to increase their efficiency. In this respect, the wind-tunnel could contribute considerably by affording means to study the airflow near the tail-surfaces, by smoke and flow investigation. It is difficult to say just what would be a desirable rearrangement of the tail surfaces, but a higher location of the horizontal tail similar to the arrangement often used for seaplanes would seem to be effective.

As regards the relative importance of the horizontal and the vertical tail-surfaces, it is my opinion that the rudder action is of utmost importance in spinning, and that efforts should be directed toward increasing its efficiency by preventing its shielding.

Positive Means of Recovery

It is almost certain that, in attempting to find a remedy for spinning, it is best to concentrate attention on means of aerodynamic control rather than on change in the distribution of masses. The design of an airplane is subordinated to its purpose; comfort of passengers, visibility of the pilot, offensive and defensive ability, and so forth, dictate the arrangement of the component parts and the location of various units of the airplane, and we must accept them as such.

However, aerodynamical means are unlimited; we are but skimming the surface with our rather uncertain efforts to find a definite control that will enable a pilot to recover from a spin. Whatever the remedy may be, it must definitely provide a pilot with means of recovery irrespective of the kind of airplane and the kind of spin.

Use of the Front Slot

Very interesting experiments are being made to use the action of the Handley-Page automatic front slot as a means of recovery. The tests made so far are very promising, but no definite information is yet available. It is beyond any doubt that the use of the automatic front slot precludes the possibility of an incipient spin and constitutes a powerful and positive means of recovery from a normal spin.

I do not know, however, of any authentic tests on the use of the front slot in a flat spin, and therefore refrain from making a definite statement. But it is my belief that, in case of a flat spin, the guarantee of the successful use of the Handley-Page slot may be doubted and its beneficial effect can be expected only in a possible change in equilibrium condition rather than on a large anti-rolling couple effective in a normal spin. I base this opinion on the fact that, for high angles of attack occurring in flat spins, the slot cannot prevent burbling of the airfoil and thus cannot cause any noticeable improvement in the available lateral control. This is merely an opinion and I sincerely hope that experiments will not confirm my doubts, since if they show that the doubts are unfounded we shall have in the automatic front slot a definite means of recovery.

In searching for means of recovery, it occurred to me that it would be interesting to investigate the possibility of using automatic leading-edge slots on the horizontal tail-surfaces. It is a generally accepted fact that the present sizes of horizontal tail-surfaces ordinarily used on modern designs are ample to take care of normal flying conditions, including adequate control at low speeds. The standard sizes and disposition of tail-surfaces are, however, often insufficient to overcome the precessional pitching moment, and it has been suggested that the average size be increased by about 30 to 40 per cent to provide for this emergency. The automatic front slot on the stabilizer suggests itself as a logical remedy, because, in normal flying, the tail-surfaces would still be unchanged, while for emergency there would be available an effective increase of tail-

(Concluded on p. 527)

Axle Ratios and Transmission Steps

By CARL D. PETERSON[1]

ANNUAL MEETING PAPER — *Illustrated with* CHARTS AND DRAWINGS

STATING that improvements can be made in the smoothness, flexibility and economy of motor-cars by the provision of axle ratios and transmission steps that will make high road-speeds possible with lower engine-speeds than at present, and without increasing the size of the engine, the author presents arguments for the provision of two quiet and efficient gear-ratios.

He asserts that the desired result can be obtained with either a two-speed rear-axle or a four-speed transmission having a quiet geared third speed, and a discussion is given of the considerations that determined the ratios actually selected in an experimental car fitted with a four-speed transmission having an internal-gear train for obtaining the third speed.

Charts are included which show the car speeds at various engine-speeds and the grades that can be climbed with the several gear-ratios.

The beginning of a tendency toward the use of transmissions of this type in Europe is reported at the conclusion of the paper. The advantages resulting from the construction are said to justify its use, provided the gear ratios are well chosen.

DURABILITY, smoothness, flexibility and fuel and oil economy should be characteristics of all modern automobiles. Almost all of today's cars have a high degree of durability and reliability; however, improvement can be made in securing increased smoothness, flexibility and economy by selecting axle-ratios and transmission steps that make possible the present high road-speeds at engine speeds which are considerably lower than those generally resorted to, without the use of larger engines for a car of given weight.

It is safe to say that one of the major causes of the roughness and noise that play on the car-user's nerves is the result of high axle-ratios and high engine-speeds at average car-speeds. This is true to an appreciable extent also after vibration dampers, carefully balanced propeller-shafts, cushioned drives, and the like, are provided as a means of reducing vibration and gaining smoothness.

With a few exceptions, axle ratios have been made high and wheel diameters decreased to secure high-gear flexibility with three-speed transmissions, resulting in high engine-speed with even moderate car-speeds. This condition gives flexibility at a sacrifice of smoothness and economy.

Another alternative resorted to is a low axle-ratio and a larger engine than would be required with a high axle-ratio and three-speed transmission for the same flexibility. The larger and heavier engine necessitates larger clutch, transmission, propeller-shaft, axles and other parts; in short, nearly every part of a car would be increased in weight, resulting in higer cost to the manufacturer and purchaser, and such a car would be likely to cost more to operate.

Experimental Car Described

With the idea of securing high car-speeds at considerably lower engine-speeds, to reduce vibration set up by the engine at high engine-speed and secure greater smoothness, and of establishing a load condition on the engine in the high-gear range to give economical fuel consumption, a car was produced having the following general characteristics:

Curb weight, sedan	3300 lb.
Weight, with driver and observer	3700 lb.
Frontal area	27.5 sq. ft.
Rolling diameter of wheels	29 in.

The car is driven by a six-cylinder engine having $3\frac{3}{8}$-in. bore and $4\frac{5}{8}$-in. stroke, giving a piston displacement of 248 cu. in. Horsepower and torque curves of the engine are given in Fig. 1.

After considering the forces that absorb the kinetic energy of the engine, namely, friction between the engine and the driving wheels, road resistance, air resistance and grade resistance, it was calculated that at the maximum horsepower output of the engine, at approximately 3100 r.p.m., the car should have a speed of approximately 72 m.p.h. and that the rear-axle ratio should be 3.72 to 1. The low-gear ratio was arrived at on the assumption that at the maximum horsepower output of the engine the car should be able to climb a grade of 20 to 25 per cent in first speed. A low-gear ratio of 14.6 to 1 was decided upon, which gives a grade ability of a little more than 23 per cent.

This axle-ratio gives high car-speeds and relatively low engine-speeds at normal car-speeds, and the low-gear ratio gives ample hill-climbing ability without making the low-gear ratio so high that it will be used as an emergency speed only, and not for starting.

Quiet Internal Third-Speed Gear

Four speed-reductions give an added flexibility that is not available with three speed-reductions; however, to secure the full advantage of four speed-reductions, two of the four must be efficient and quiet. One of them can be either an extra speed in the rear axle, in one form or another, or an internal-gear reduction replacing the noisy third-speed spur-gear reduction of a conventional four-speed transmission. The internal-gear reduction has been provided in the transmission of the car being considered.

The quiet and efficient internal-gear reduction carried in the transmission supplements the high or fourth-speed reduction and gives results identical with those of a two-speed rear-axle having gear ratios the same as the third and fourth-speed ratios. This third speed provides a quiet high-speed driving-range giving a

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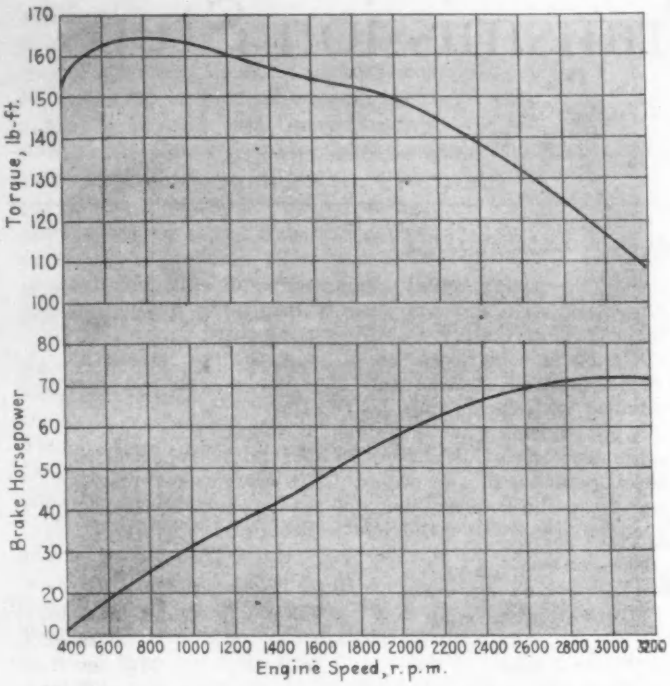

FIG. 1—HORSEPOWER AND TORQUE CURVES OF ENGINE FOR EXPERIMENTAL CAR

high accelerating and hill-climbing ability at relatively high car-speeds.

In determining the second and third-speed ratios it was found that, with an arithmetical progression[2], the total ratios and transmission ratios would be substantially as follows:

	Total	Transmission
First Speed	14.60–1	3.92–1
Second Speed	7.21–1	1.94–1
Third Speed	4.91–1	1.32–1
Fourth Speed	3.72–1	1.00–1

With a geometrical progression, the total gear-ratios and transmission ratios would be:

	Total	Transmission
First Speed	14.60–1	3.92–1
Second Speed	9.23–1	2.55–1
Third Speed	5.86–1	1.62–1
Fourth Speed	3.72–1	1.00–1

In Fig. 2 is given a speed-grade chart showing the engine and car speeds and the grade characteristics. Assuming that the engine has a momentary speed of 2000 r.p.m., it will be seen from the chart that the car will climb a 5.3-per cent grade at a speed of 68.3 ft. per sec., which corresponds to a car speed of about 46.5 m.p.h. Should a steeper grade be encountered the car speed would be reduced, unless a shift were made to third speed. A three-speed car having the usual high axle-ratio would possibly maintain its speed under the same grade conditions without shifting into second gear; however, this performance would be secured at higher engine-speed, sacrificing to an appreciable extent the smoothness, economy and high average accelerating-ability during approximately 90 per cent of the driving time.

The high ratio of a two-speed rear-axle or the quiet third-speed of a four-speed transmission can be arranged to give the same or better performance for hill-climbing and traffic acceleration, at the same time securing these desirable characteristics which are not obtainable with the commonly used three-speed ratios.

At the same engine-speed, if the third speed of the arithmetical progression is engaged, the car will climb a 9.3-per cent grade at a speed of 52 ft. per sec., or about 35.3 m.p.h.; and if the third speed of the geometrical progression is engaged the car will climb a 12.5-per cent grade at a speed of 43 ft. per sec., or 29.2 m.p.h.

Speed Ratios Selected

From experience with four-speed ratios it is generally agreed that, with the arithmetical progression, the step between third and fourth speeds is not great enough and shifts into second speed are too often necessary on hilly roads. To reduce gearshifting, the third speed of the geometrical progression would be more acceptable; however, this step is too great for universal use. For the third speed of the transmission of the car under consideration, a third-speed ratio of 5.18 to 1 was selected, which falls between the third-speed ratios of the arithmetical and the geometrical progressions. At an engine speed of 2000 r.p.m. this would enable the car to climb a 10-per cent grade at a speed of 50 ft. per sec., or about 34 m.p.h.

The second-speed ratio of the geometrical progression should be more desirable than the arithmetical progression, as it would prevent too frequent shifts into first speed. A second-speed ratio of 8.89 to 1 was selected, which approaches very closely the second speed of the geometrical progression.

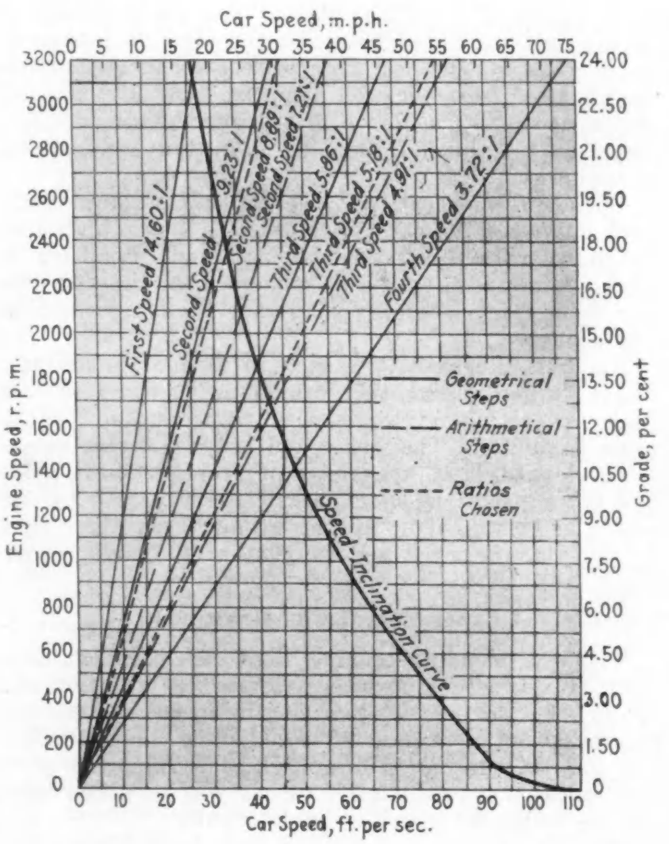

FIG. 2—SPEED-GRADE CHART FOR VARIOUS GEAR-RATIOS

[2] To make these ratios appear as an arithmetical series, it is necessary to express them as decimal equivalents of 1/14.60, etc.—Ed.

The total and the transmission ratios selected for the car are as follows:

	Total	Transmission
First Speed	14.6–1	3.920–1
Second Speed	8.89–1	2.391–1
Third Speed	5.18–1	1.394–1
Fourth Speed	3.72–1	1.000–1

The reverse ratio should be equal to or greater than the low-gear ratio. For this car it was made equal to the first-speed ratio.

Performance Shown by Charts

Relative car and engine speeds in high gear are plotted in Fig. 3 for the four-speed car and for a similar car having a 4.62-to-1 rear-axle ratio. The four-speed car has a top speed of 71.8 m.p.h. at an engine speed of 3100 r.p.m., at which speed the maximum horsepower is developed. For the same engine-speed the three-speed car has a speed of 57.8 m.p.h.;

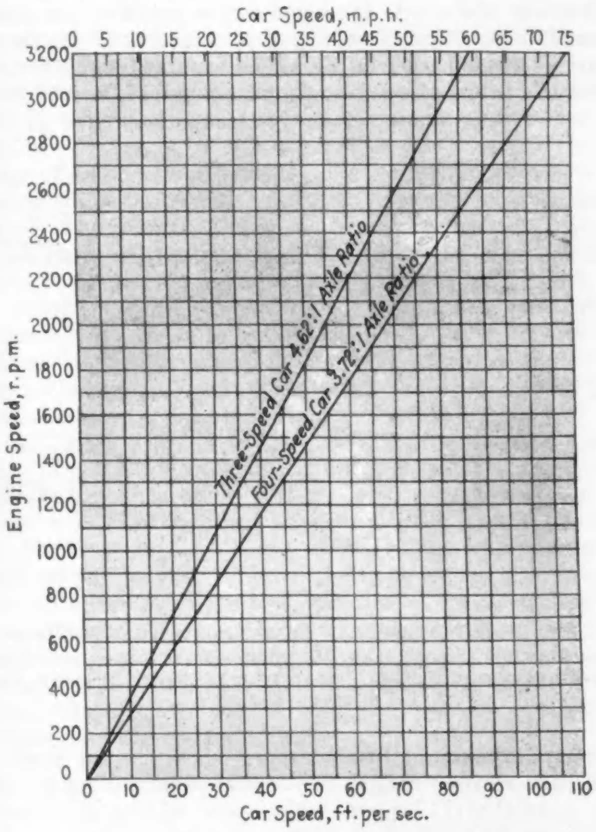

Fig. 3—Relative Car and Engine-Speeds

and for any engine-speed the four-speed car has a speed 24 per cent greater than that of the three-speed car. A comparison of engine speed at 40 m.p.h shows that the four-speed car has an engine speed of 1730 r.p.m., while the three-speed car has an engine speed of 2150 r.p.m. The engine speed of the three-speed car always is 24 per cent greater than that of the four-speed car for the same car-speed. This difference is appreciable, considering that about 90 per cent of the driving time is consumed in the fourth speed. Not only does this give very smooth operation, because of reduced vibration, but it reduces substantially the wear of the engine and the power-transmission parts.

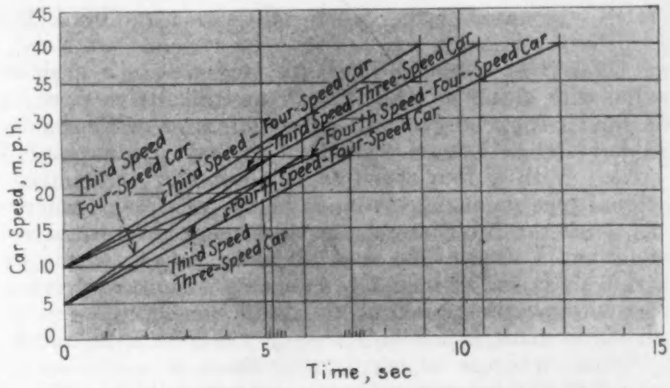

Fig. 4—Comparison of Acceleration for Two Cars

The acceleration of the four-speed car in fourth and third speeds, and of the three-speed car with 4.62-to-1 axle-ratio in top speed, are given in Fig. 4 for from 5 to 25 m.p.h. and from 10 to 40 m.p.h. The improvement in maximum acceleration by supplementing a low axle-ratio by another ratio is clearly brought out.

In the transmission used in the experimental car, the first and second-speed and reverse reductions are through spur gears, while the third-speed reduction is obtained through constantly meshed internal-gears. The inherent quietness and high efficiency of such gears makes them desirable to supplement the fourth speed and thus broaden the quiet-driving range.

The sliding spur-gears are shifted in the conventional way, and the third and fourth speeds are picked up by a sliding clutch so designed as to permit changing from third to fourth or from fourth to third at high speeds without clashing, as described in a previous paper[3] by C. A. Neracher and Harold Nutt. This clutch is controlled by the same lever that controls the sliding gears. None of the forward speeds is latched out, as the transmission is recommended for use as a four-speed unit and has the ratios so arranged that it is deemed advisable to use them all. The provision of a lower gear-ratio for a passenger-car seems unnecessary and is resorted to only in few instances. The reverse is latched out in this transmission as a safety measure, to prevent the possibility of picking it up when shifting between third and fourth speeds.

One prominent European manufacturer, who formerly used four-speed transmissions in his cars, has lowered the axle ratio in one of his models during the last year and supplemented it with a four-speed transmission having an internal-gear third-speed. The reaction from the field was such that now another model is being brought out with the same form of transmission. Several other European manufacturers are contemplating making a similar change in their cars.

It seems to be generally agreed that a transmission having less than three speed-ratios would be of no real value in a modern automobile, but there seems to be a doubt in some engineers' minds as to the desirability of more than three speed-ratios; nevertheless, there are certain distinct advantages that justify the use of a fourth ratio, regardless of whether it is placed in the axle or in the transmission, provided the gear ratios are well chosen. Mean piston-speeds are lowered, vibration and wear are reduced, car speed is increased, fuel economy is improved, smoothness over a wider range is secured, and better acceleration for a given engine and weight of car is obtained.

[3] See S.A.E. Journal, February, 1927, p. 247.

THE DISCUSSION

C. A. NERACHER[4]:—The functioning of a transmission with either an overdrive or an underdrive through a double-internal-gear set in combination with a suitable clutch is exactly equivalent to that of a two-speed axle. With a four-speed transmission of the conventional type no change is made in the axle ratio; whereas, with the internal-gear type, a much lower total reduction is used. The over-all reduction between the crankshaft and rear axle is the same with underdriving as with overdriving, but the reduction in the fourth speed is made in a single step at the axle with underdriving, whereas in overdriving there is a step-up in speed at the internal set and a correspondingly greater step-down in speed at the axle drive-gear. Consequently, internal gears arranged for underdriving make for better, lighter, and cheaper rear axles.

For example, a particular car with which I have experimented was equipped with a three-speed transmission and an axle having a 4.5-1 ratio. By equipping this car with a four-speed underdriven transmission, I found that the third speed, which was through the internals, gave the equivalent of 5.3-1 axle-ratio. If this car had been overdriven, an axle ratio of 5.3-1 would have been required, but with underdriving the ratio was 3.7-1.

The 3.7-1 axle-ratio permits a larger pinion, a smaller ring-gear, or a combination of both. The smaller ring-gear makes possible a correspondingly smaller axle-housing, less unsprung weight and increased ground-clearance. We are all familiar with the difficulties of hardening, straightening and heat-treating large ring-gears. While underdriving improves axle conditions, compared with conventional construction, overdriving makes them worse. Conventional rear-axle ratios are all compromises, and bad ones. We want higher rear-axle ratios for acceleration, hill climbing and traffic performance. On the other hand, we should like lower rear-axle ratios for reduced engine-speeds at higher car-speeds and for general driving comfort at ordinary car-speeds. With three-speed transmissions, we cannot get the best ratio combinations for modern traffic conditions. We therefore select some ratio that is a compromise, and it gives a performance that is also a compromise.

Avoiding a Compromise

With a two-speed axle or a four-speed internal-gear transmission, we can get ratios exactly suited to best performance. We therefore select one higher ratio, for improved acceleration and ability, and another lower ratio, for high car-speeds with lower engine-speeds. The same ratio-choice must be made whether underdriving or overdriving is used. With overdriving, if over-all ratios are properly arranged, an axle-reduction greater than usual will be required, making a poor axle-condition. There would be little if any advantage in the use of a four-speed transmission unless the top-gear ratio were reduced from conventional three-speed practice, as that would merely provide for making the shifts in four short steps instead of three longer ones.

Overdriving makes the propeller-shaft speed about 40 per cent higher than underdriving. I believe this to be very undesirable, even though the increase in speed causes reduction in the load on the parts. Any possibility of reduction in size because of that would be entirely offset by the increased tendency to whip, with the result that the higher-speed shaft would be more expensive and troublesome than the lower-speed underdriven shaft.

In the transmission itself, comparative results of arranging gears for overdriving or underdriving are most important. It is essential that the bearings be quiet in a transmission of this type, and I assume that the importance of quietness would influence designers in their selection. Low pitch-line and ball-bearing speeds are important; and overdriving results in higher speeds, as can be shown by a comparison of concrete cases.

Speed of Parts Compared

With either construction the driving-end speed is identical, since it is the same as the speed of the engine crankshaft. For illustration, let this speed in the two sets of gears shown in Fig. 5 be assumed as 1000 r.p.m. and the internal-gear combinations as 17-21 and 31-35.

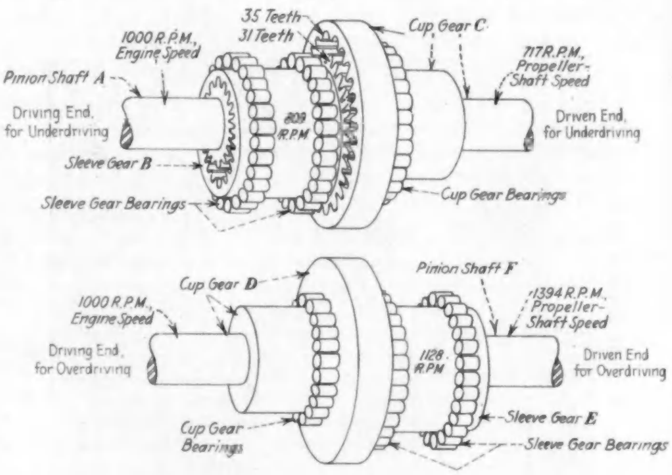

FIG. 5—INTERNAL-GEAR TRAINS FOR A TRANSMISSION
This Diagram Shows How the Same Gear-Ratios Give Lower Speeds to the Parts in Underdriving (Above) than in Overdriving (Below)

For undergearing, in the upper view, pinion shaft A will turn at 1000 r.p.m., sleeve gear B at 809 r.p.m., and cup gear C at 717 r.p.m. The speed of the sleeve gear is 81 per cent and that of the cup gear is only 72 per cent of the engine speed. Assuming the same engine-speed for the overgeared combination shown in the lower view, cup gear D will turn at 1000 r.p.m., sleeve gear E at 1128 r.p.m., and pinion shaft F at 1394 r.p.m. Therefore, the speed of the sleeve gear is 11¼ per cent greater than the crankshaft speed, and the pinion shaft rotates 39½ per cent faster than the crankshaft.

Bearing and Tooth Speeds Improved

Since it is assumed that the gears and bearings are of the same sizes throughout in both cases, we have a striking contrast in the operating conditions. In the case of overdriving, the velocities of the teeth and bearings of both the cup gear and the sleeve gear are 39½ per cent greater than the corresponding velocity of the underdriven combination. Moreover, the pitch-

[4] M.S.A.E.—Chief engineer, Durant Motor Co. of New Jersey, Elizabeth, N. J.

line velocity of the pinion-shaft teeth is 94 per cent greater with overdriving than with underdriving at the same engine-speed, and about $39\frac{1}{2}$ per cent greater at the same car-speed. The effect of such a speed difference on smoothness of propeller-shaft operation can easily be imagined.

Such reductions in velocity go a long way toward solving problems of noise and vibration, especially when the rotating parts are of comparatively large diameter; and it is structurally necessary to have large bearings in internal-gear transmissions, because of telescoping parts. Moreover, the saving with underdriving is actually greater than this comparison shows, because it is necessary to provide gears and bearings of larger diameter with overdriving owing to the fact that low-gear and second-speed reductions are ahead of the internal unit and multiply the load.

An even more important reason for underdriving is that, when the gear ratios are properly arranged, the car can be driven in the top gear about 90 per cent of the time. While the internal gearing is very efficient, the loss through the double set of internals being only about 2 per cent, the over-all efficiency of the car should not be penalized even that much during 90 per cent of the time when it is necessary only 10 per cent of the time. The only justification for overdriving seems to be under conditions that demand the use of the third speed, which in that case is the direct drive, a greater percentage of the time than fourth or top gear. I have personally had no experience with such conditions.

Another point is that there is a certain amount of noise when a drive is transmitted through even internal gears. At high car-speeds an overdrive, with its inherently higher bearing and pitch-line speeds, multiples the noise, which is made more audible because of the lower speed and therefore quieter and smoother operation of the engine. With underdriving, all of these conditions are reversed. At high car-speed with a low engine-speed, the gears are not loaded, as the drive is direct, and the pitch-line speeds and bearing speeds are both vastly lower. When running in traffic, accelerating or hill climbing, with the underdrive operating—which is not usually done at high car-speeds but at relatively high engine-speeds—any slight transmission noises from the bearings or gears of a well-made internal-gear transmission are almost entirely blotted out by the accompanying engine noise.

Three-Speed Form Advocated

E. S. MARKS[5]:—Having driven cars equipped with comparatively low axle-ratios, say 3.5-1 to 3.9-1, I am in entire accord with the writer of this paper in his statement that lower engine-speeds at higher car-speeds cause a reduction in what might be termed general noises. The more quiet operation resulting adds greatly to the comfort of high-speed driving. Granting that we are agreed on this point, the problem becomes one of how best to attain this objective.

Car designers are faced with the fact that the American public has been educated to expect maximum flexibility without gearshifting. In other words, in each succeeding design, power-to-weight ratios have usually been increased so that new cars will take certain pet hills on high better than their predecessors. Mr. Peterson's four-speed experimental car shows less acceleration and hill-climbing ability in fourth speed than the corresponding three-speed car does in third. It must be remembered that the better performance he reports is obtained after the shift has been made from high gear to third.

I do not believe that the advantage of a quiet speed next to high gear has been given the attention it deserves. The internal-gear idea, incorporated in a three-speed transmission having gear-ratios suitable for the car weight, gives a start from the curb in second gear without gear noise and also an exceptionally high degree of noiseless flexibility in traffic.

The lower engine-speed at high car-speed is desirable. The question is: Will the best all-round satisfaction be obtained by asking the owner to shift more often than he has been accustomed to do, or will he demand the smoother and more comfortable operation at high car-speed without shifting? The latter result can be obtained by getting more power out of an engine of a given size, an increase in the cubic capacity of the engine, or a decrease in the weight of the car. The months immediately ahead will give the answer.

Economy Sacrificed for Performance

H. M. CRANE[6]:—The slowing down of the engine in passenger-cars at high car-speed, as described in Mr. Peterson's paper, certainly is very desirable for reduction in wear and tear on the engine and in gasoline consumption. Oil consumption also is highly affected by engine speed; it apparently goes up something like the cube of the engine speed, or some such violent ratio.

To the car builder, the questions are: How many people drive at high speeds? How much do they care about gasoline consumption? How much do they care about freedom from gearshifting? How much do they care about extreme acceleration in top gear? I think that manufacturers have been crazy in vying one with the other in emphasizing the importance of certain things like the ability to accelerate in high gear and hill climbing in high gear. We might have made our jobs much easier if we had not over-emphasized such qualities, which we know can be obtained only by definite losses in other directions. I think that the two cars indicated in the paper would show high-gear fuel-economies about in proportion to their rear-axle ratios.

We have quite another case in the motor-truck transmission. The four-speed gear is rapidly becoming universal in trucks, because of the necessity for an emergency starting-gear much lower than is required for the normal passenger-car. One reason is that the truck user has found, by experience, how conservative we are in rating the load capacity of our vehicles. Probably the most commonly used 2 and 3-ton trucks are the Chevrolet and the Ford. You cannot expect to pull a Chevrolet truck out of a tough hole with a three-speed transmission and a passenger-car first-gear reduction, even with a greater rear-axle reduction. It can be done only by speeding up the engine and using the inertia of the flywheel, which is too hard on the clutch and the whole car.

In heavy trucks the same thing holds true, especially in New York City, where the excavated material from virtually every building operation is moved by trucks driving out of the excavations, to avoid blocking the streets while loading. It always astonishes me to see

[5] M.S.A.E.—Chief engineer, H. H. Franklin Mfg. Co., Syracuse, N. Y.

[6] M.S.A.E.—Technical assistant to president, General Motors Corp., New York City.

a big Mack truck come out of one of those excavations on what looks like a 45-deg. grade. It is not that bad, but it is pretty steep. It can be done only by having a tremendous reduction between the engine and the rear axle. Quietness is not a requirement for trucks.

Quietness of Internal Gears Questioned

No doubt we should all be building four-speed gears if all passenger-cars were operated much at 60 to 70 m.p.h., and if we could make such gears quiet and at reasonable cost. With all due respect to the qualities of the internal-gear four-speed arrangement, if would not be possible with it to make any ordinary owner think that he had two direct drives, certainly not after his car had been run for a little while.

I watched a car with such a transmission on the General Motors proving grounds last year. It was not driven particularly hard or with the gears in use a great deal of the time. I used to try it every time I went out there, perhaps once a month. It was obvious that the job was slowly deteriorating as to quietness. When it was new it would have been rather easy, in town with some noise around, to make an owner believe that either gear was direct. After six months of operation, which I think represented 5000 or 6000 miles, a man who had not been in the car all the time would never have been convinced that the two gears were alike, although the owner might have felt that it was all right still because the change was so gradual.

The question of gear ratios has always been very interesting to me, and it is one that I think has never been completely solved in this Country. The conditions affecting axle ratios have changed during the last 10 years, and especially during the last 5 years, because of the great number of traffic lights which increase the occasions for starting from a standstill in competition with other vehicles.

Old Experience with Four Speeds

I have looked up the axle ratios and transmission ratios that we used in four-speed and three-speed designs about 15 years ago. The gear ratios in the four-speed transmission of the Crane-Simplex, which had a 563-cu. in. engine and usually a 3.5-1 or 3.2-1 rear-axle ratio, were 1-1 on high, 1.41-1 on third, 1.96-1 on second and 2.82-1 on first. The reverse was somewhat slower than first gear. The car weight, fully loaded except for passengers, was in the vicinity of 5400 to 5500 lb.

There is some doubt in my mind whether that first-speed ratio was really as low as it should be, but it is very difficult to get a good four-speed transmission having the first speed as low as you would like it without either getting some very awkward combinations in the other gears or having to sacrifice the use of ball-bearings throughout—as this car had, even for the spigot bearing. That has a lot to do with determining what the first gear below the top ought to be.

If the owner drove to almost a stalling point on high gear in climbing a hill with that car, and made a prompt shift into third, he could just barely keep going; but, if he fumbled the shift or the operation of the throttle at that time, he would probably lose speed sufficiently to have to go back to first or second speed.

I believe that if the spigot bearing, where there is a tendency to bind, and the countershaft bearing had been plain bearings, the third speed would have been nearly useless for hill climbing. Many of the cars at the General Motors proving ground have a step of from 1-1 in third speed to 1.96-1 in second speed; and they will just barely keep going if they are driven on a hill in high gear almost to the stalling point and then shifted into second gear.

More for amusement than for anything else, I laid out a car after the war. In this I used a three-speed transmission, such as we had had some experience with building before. The ratios selected were: 1-1, 1.55-1, and 2.86-1. These ratios leave something to be desired after a drop from high to second, but they are fine for getting away in traffic in second gear. A car having these ratios, which we built in 1912, is still running and in the possession of my brother in New York City. It has a fairly high axle-reduction and a very large engine for its weight—360 cu. in. for about 4000 lb., or 0.9 cu. in. per lb.—and my brother has never found a car that could get away as well at a crossing.

Traffic Starting as Acceleration Test

It is strange that starting at the traffic lights has received so little consideration as a car test. No owner can tell accurately the difference between the accelerations in high gear of two cars from 5 to 25 m.p.h., but he can tell the difference that appears in getting away from a standing start. The common view of the influence of big axle-reduction on acceleration is a fallacy. This does not help in accelerating through the gears, although it may help in high-gear tests.

Conditions as to resistance are very bad in a car having a low second-gear, especially if the moving parts in the engine and transmissions are heavy. In some cars, acceleration of the flywheel, crankshaft, and other parts is the main job of the engine in low gear.

In my opinion, even with three-speed transmissions, the car with the 3.72-1 axle ratio, described by Mr. Peterson, would get away faster than the other with the gears in use, because of much more favorable conditions in second speed. What has discouraged me most from a long experience with the four-speed transmission is that drivers in general are not intelligent enough to get the results they should from it. A while ago we had a Rolls-Royce car at the proving grounds. Some of the experienced drivers had to be informed that all four speeds are rarely used in starting. On a level road, such a car should generally be started in second and shifted directly into high, unless there is some particular reason for hurrying the start by using third speed. On an up-grade, the car should be started in first, shifted into third and then into fourth; and, on a down-grade, it should almost always be started either in third or fourth.

It is my theory, and I think it is commercially correct, that nothing that costs much should be put into a car that is expected to have a large sale, unless it will be of value to considerably more than one-half of the purchasers. I doubt whether half of the owners of cars of most models are driving faster than 40 m.p.h. For that reason I am still in considerable doubt about the desirability of four-speed transmissions. Certainly the public will need to be educated to use them. Perhaps someone will begin the education. If the public shows a desire for this feature rather than for some other that can be supplied at the same cost, we shall all put four-speed transmissions into passenger-cars, as we have in trucks.

Four Speeds Desirable for All Cars

G. C. MATHER[7]:—Entering the parts field has brought me into contacts with engineers of various motor-car companies that are different than when I was with the Graham-Paige Motor Corp., and it has been a surprise to find the differences in opinion that exist regarding the four-speed transmission. Some engineers believe that if the ratio between engine displacement and weight is favorable enough there is no need for a four-speed transmission; others feel that a four-speed transmission should be used in conjunction with a relatively small engine and frequent gearshifting should be expected.

In my opinion, both of these lines of thought are incorrect. Any automobile that is so geared as to provide, with a three-speed transmission, the performance that the American public demands is geared entirely too slow for more than 90 per cent of the driving under even very hilly conditions. Any car can be geared faster if a four-speed transmission is used, and the highest gear will be used for most of the driving. Present standards for weight and engine displacement should be followed, and the four-speed transmission should be installed as a further refinement. It is true, however, that a four-speed transmission will make passable an underpowered car that would otherwise be unsatisfactory.

We believe that a four-speed transmission is not only desirable but necessary to slow down the engine speed. With ratios in use today, most engines, at a car speed of 60 m.p.h., are rotating at from 3100 to 3500 r.p.m., and some even faster. With one four-speed installation on a very successful make of automobile, the engine speed at 60 m.p.h. is 2497 r.p.m., which is approximately 25 per cent slower than it would be with a three-speed transmission.

No attempt has been made so far to obtain greater car-speed by using a four-speed transmission. The car to which I have referred had the same maximum speed with either a three-speed or a four-speed transmission. The rear-axle ratio was approximately 3.7-1 with the four-speed transmission and 4.8-1 with the three-speed transmission. Higher road-speeds could have been obtained by using 3.9-1 or 4-1 ratio in the rear axle with the four-speed transmission, but at a sacrifice because of increased engine-speed during most of the time the car was on the road.

Undergearing or Overgearing

One of the most common arguments is as to whether the undergeared or overgeared type should be used. Using a transmission of the overgeared type is the first step toward becoming a four-speed advocate, as by its use the engine can be slowed down without changing the rear-axle speed at the expense of higher propeller-shaft speed. This type has a number of disadvantages, however, as compared with the underdrive type. The more experience the engineer has with the four-speed transmission, the more he finds that the third speed has to be used very little. That being the case, there is no object in driving through a set of intermediate gears for the greater portion of the car miles covered.

A further good reason for using the underdrive type is for slowing down the propeller-shaft. Many complaints of rough engines, when traced to their source, are found to be due to roughness of the propeller-shaft at high speeds because of unbalance. Slowing down the propeller-shaft by using a four-speed transmission is a simple means of removing faults of that nature. The problem of making quiet axle-gears is greatly simplified with the undergeared type of transmission because of the greater number of teeth in the pinion.

Many people ask above what speed fourth gear can be used. In most installations, fourth gear will be found entirely satisfactory above 10 or 15 m.p.h. One of the questions which all are interested in is whether third gear is quiet. Considered as a gear installation, it is. In most cases the noise in third speed is less than in axles which the average car-manufacturer's inspector would approve for shipment; however, it is usually possible to hear some slight noise.

How fast a car will run in third gear depends entirely upon factors such as engine characteristics, car weight and gear ratio. The car to which I have referred has been run faster than 65 m.p.h. in third, but why any owner should want to drive at such speeds in third is a question I am unable to answer. It is to take care of high speeds that a fourth gear is installed.

One point in which there is a great deal of interest is that of economy of operation. Fuel consumption is improved approximately 25 per cent and oil consumption to a much greater degree, depending somewhat on the proportion of driving at high speeds. Engine and chassis upkeep are also reduced very considerably.

My opinion is that before long the many good features of the four-speed transmission will induce car builders to install this type as standard equipment. The satisfaction of riding continuously at high speed without the roar and noise usually associated with high speed cannot be appreciated until a trip under owner-driving conditions has been experienced. The result usually is a greatly increased number of car miles without fatigue, or a very noticeable shortening of the time.

The condition of having available two gear-ratios which enable the same automobile to give a heretofore unattainable degree of performance in both level and hilly districts is very gratifying. Also, the manufacturer's problem of having different gear-ratios to ship to different parts of the Country is eliminated.

Varied Requirements of Different Cars

F. C. THOMPSON[8]:—The improvement in operation obtained in any car from two comparatively quiet high speeds is so great that one tends to overlook the possibility of further improvement. The subject of transmissions, axles and their ratios should be considered for cars of all makes, sizes and types, rather than with reference to any specific case.

Considering that the weight of passenger-cars being built today by prominent manufacturers varies from 16 to 12 lb. per cu. in. of piston displacement and the axle ratios required to obtain the desired acceleration and hill-climbing ability vary from 3.2-1 to 5.6-1, it is reasonable to assume that consideration should be given to more than one type of transmission. We are all striving for results, and there is a great variety of conditions from which the same final results must be obtained.

Our company has been building sample transmissions of the internal-gear type continually for the last five years for a large number of automobile manufacturers,

[7] M.S.A.E.—Sales, engineering, Warner Gear Co., Detroit.

[8] M.S.A.E.—Manager, Morse Chain Co., Detroit.

to be installed in cars with engines of almost every size from 110 to almost 400-cu. in. displacement. We are now building 18 samples for installation in cars of seven different makes. Some of these samples have four speeds with direct drive on third, some have four speeds with direct drive on fourth, and some have three speeds with direct drive on third.

We want it definitely understood that we are not condemning the four-speed transmission with direct on fourth; in fact, we are much in favor of it in its proper place and feel that the manufacturers now using this arrangement have made a wise selection. We feel, however, that the two other types should not be condemned by men who have had no experience with them in the cars in which they should be used. Too many definite statements are being made by men who think they know but have not had that experience, and too many statements are being made as general that should be made with reference only to specific cases.

Our policy is to recommend to the automobile manufacturer a type of transmission based on the performance of his car with a certain axle-ratio. Virtually all prominent makes of car have approximately the same performance, although their axle-ratios vary from 3.2-1 to 5.6-1. In most cases the automobile manufacturers accept our recommendations, which usually are as follows:

(1) When satisfactory performance is obtained on direct drive with an axle ratio of 3.2–1 to 3.8–1, we recommend the three-speed transmission with direct drive on third

(2) When satisfactory performance is obtained on direct drive with a ratio of 3.8–1 to 4.0–1, we recommend a four-speed transmission with direct on fourth.

(3) Where axle ratios of 4.00–1 to 4.75–1 are required, we recommend building four-speed samples with both direct drive on fourth and on third, the choice between them to be made from actual test.

(4) Where axle ratios of 4.75–1 to 5.60–1 are required, we recommend the four-speed transmission with direct drive on third.

Selection Determined by Test

In many cases we are building more than one type of transmission for an automobile manufacturer to test. In most cases where we have questioned whether a four-speed transmission should have direct drive on third or on fourth speed, the automobile manufacturer has decided in favor of the former. The design of the transmissions tested has been identical in such cases except that the parts were so arranged as to obtain either the overgear or the undergear, which is not difficult with our design.

One discusser refers to an overdrive 40 per cent above direct drive. This is misleading, as it is not practical to have the overdrive more than 30 per cent above direct.

Referring to remarks in regard to noise at high speed on the overdrive transmission, the noise decreases as the speed increases with our design of either overdrive or underdrive transmissions and is entirely eliminated at 35 m.p.h. and upward. This has been true of every transmission of this type that we have built.

We agree that it is an advantage to reduce propeller-shaft speeds and that it is easier to get quiet axles with less reduction in the axle gears; but, if it is necessary to have a 4.75-1 to 5.60-1 ratio in the rear axle to get satisfactory car performance, we must accept these conditions as a fact or redesign the entire car; and, if the cars are all to be redesigned, we are discussing a matter that is of no value.

MAURICE J. ZUCROW[9]:—I agree with Mr. Crane that it is hard to get a person who has been used to driving a three-speed car to drive a four-speed car to good advantage. Did Mr. Peterson, in computing the acceleration ability, take into consideration the fact that part of the energy goes into accelerating the various parts of the engine? Would its consideration influence the selection of transmission ratios?

CARL D. PETERSON:—The accelerating values were measured, not calculated. They appear high, but they were determined very carefully.

DR. H. C. DICKINSON[10]:—We were interested a few days ago in a question that Mr. Crane raised as to actual acceleration from a standing start. We set up electric contacts with a chronograph on a 160-ft. straightaway and drove about 30 cars of widely differing stock types, selected at random, over this course. Calculated roughly, the average acceleration for the 160 ft., starting in first and going through the gears, ranged from 4 ft. per sec. per sec. to 8 ft. per sec. per sec. This demonstrates the wide range of acceleration in stock cars.

Power Losses in Bearings

JOSEPH B. LINCOLN[11] and FRANK R. SCHUBERT[12]:—Since most of the bearings mounted in transmissions and axles are antifriction bearings, the loss per bearing is a relatively small part of the total loss.

We have investigated the internal power-losses of a medium-series 65-mm. (2.559-in.) bore ball-bearing at various loads and speeds. This size of bearing, which has a rated capacity of 5860 lb. at 900 r.p.m. and 2000 lb. at 3000 r.p.m., is used for carrying radial load only at the axle drive-pinion of a car having the following engine characteristics: maximum torque, 330 ft-lb. at 900 r.p.m.; torque at 2400 r.p.m., 220 ft-lb.; axle ratio, 3.72, giving 60 m.p.h. at 2300 r.p.m. With these characteristics, the radial loads on the pinion ball-bearing vary from about 1225 lb. at 2800 r.p.m. to 2400 lb. at 900 r.p.m.

Tests of ball-bearings of this size in a ball-bearing testing-machine, as recorded in Table 1, indicate that the torque input to overcome the internal friction of the bearing does not increase rapidly with the speed, and at the heavier loads it is practically constant for any given load at any speed from 900 to 3600 r.p.m.

Study of Table 1 shows that, operating under 5000 lb. load, five-sixths of its rated 900-r.p.m. capacity, this bearing requires only 15-per cent more torque-input at 3600 r.p.m. than at 900 r.p.m.; hence, the power loss in the bearing is 4½ times as great at the higher speed, that is, 0.17 hp. at 900 r.p.m. and 0.76 hp. at 3600 r.p.m.

If the load is 2500 lb., approximately the rated capacity at 2500 r.p.m., the torque input increase resulting from an increase in speed from 2500 to 3000 r.p.m.—at which speed the capacity rating is 2000 lb.—is only 3

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[11] Naval Engineering Experiment Station, Annapolis, Md.

[12] M.S.A.E.—Vice-president, McGill Metal Co., Valparaiso, Ind.

per cent, but the horsepower loss is increased by 25 per cent. These speeds represent approximately what are regarded as conservative pinion-shaft speeds when slow and fast axles are mentioned.

TABLE 1—TORQUE LOSSES IN MEDIUM-SERIES SINGLE-ROW BALL-BEARINGS OF 65-MM. BORE

Engine Speed, R.P.M.	No Load		1,250 Lb.		2,500 Lb.		5,000 Lb.		8,000 Lb.	
	Torque[13]	Loss[14]	Torque	Loss	Torque	Loss	Torque	Loss	Torque	Loss
900	0.40	0.06	0.40	0.06	0.50	0.08	1.00	0.17	2.00	0.33
2,000	0.50	0.18	0.50	0.18	0.60	0.23	1.12	0.42	2.02	0.75
2,500	0.60	0.28	0.60	0.28	0.70	0.32	1.17	0.54	2.00	0.92
3,000	0.60	0.33	0.63	0.35	0.72	0.40	1.17	0.65	2.00	1.11
3,600	0.65	0.43	0.67	0.45	0.72	0.48	1.15	0.76	2.12	1.41

[13] Torque is in foot-pounds.

[14] Loss in horsepower.

Since the makers of the particular car under consideration have selected a pinion bearing to operate at one-half its rated capacity, we should next compare the torque input and power losses at one-half the rated capacity at 2500 r.p.m.; namely, 1250 lb. Increasing the speed from 2500 to 3000 r.p.m. causes a 5-per cent increase in torque-input loss; hence, the power loss is 25 per cent greater.

These power losses in antifriction bearings are small when considering over-all efficiency, provided proper care is used in selecting the correct size of bearing for the job; however, if a selection is made that results in occasional overload, the bearings undoubtedly will stand up but the power losses become greater. To illustrate: in the bearing under consideration, operating at 3000 r.p.m. at one-half rated capacity the power loss is 0.35 hp.; at rated capacity it is 0.40 hp.; at twice rated capacity it is 0.65 hp., and at three times capacity it is 1.00 hp.

The torque-input and power-loss figures given were obtained by testing four 65-mm. bearings mounted on a solid arbor, so they are averages for four bearings.

Developments in Lighter-than-Air Craft

(*Concluded from p.* 473)

The Puritan has a gas capacity of 86,000 cu. ft. and is helium inflated. It is equipped with two 70-hp. radial engines, and attains a speed of 55 m.p.h. Maneuverability has been increased by the addition of an upper balanced rudder. It was launched August 6, 1928, and in the succeeding 60 days flew 8000 miles, carried more than 600 passengers, and ran up a total of 180 hr. in the air. Its range, carrying two passengers, a mechanic and a pilot, is 417 miles. Its longest non-stop flight up to December, 1928, was over the mountains from Akron, Ohio, to Lakehurst, N. J., a distance of 410 miles.

Three ships of the Puritan type are now under construction. A larger ship of 160,000-cu. ft. capacity, having two 150-hp. engines and capable of carrying nine passengers, is also being designed.

Utility of Small and Large Airships

The utility of small non-rigid airships is perhaps open to question. It is not expected that they will compete with airplanes in the carrying of mail and on short flights, but they possess a great advantage in that they have proved conclusively their ability to land in the smallest and poorest of fields and even on the flat roofs of downtown office buildings. Commercially they are desirable as a means of advertising and of creating good-will. The larger semi-rigids and the smaller rigid ships are very suitable for aerial photography, surveying and map making. In a military sense the small non-rigid ships are extremely valuable for "spotting" and anti-submarine work. For observation purposes the airship has unique advantages, because of its ability to remain in the air for long periods or even to float motionless with engines stopped.

A discussion of the lighter-than-air ship would not be complete without a few words concerning the relation existing between it and the airplane. While realizing the advantages of the airplane as a commercial vehicle for carrying comparatively light loads over medium distances at high speeds, the designers of rigid airships have turned their efforts to the erection of large, safe, and reliable ships that will be capable of bettering present methods of transportation over large stretches of land and ocean. Successful completion of the present projects will give added impetus to the present growing appreciation of the airplane. Of what use will be the saving of several days in an ocean voyage by airship if hurrying passengers end their flight only to find nothing but primitive overland travel available for the rest of their journey? The two branches of air travel must advance hand in hand, working not as units but as a group in an attempt to speed up transportation to any and all parts of the world.

Vapor-Pressure Data on Motor Gasolines[1]

By Oscar C. Bridgeman[2], Elizabeth W. Aldrich[3] and Hobart S. White[4]

Annual Meeting Paper — *Illustrated with* Charts and Diagrams

THE REPORT deals specifically with that part of the Bureau of Standards' program involving vapor-pressure measurements. A description is given of a method and apparatus for the removal of dissolved gases from dried gasolines, without appreciably affecting the propane content and without otherwise changing their composition.

Vapor-pressure measurements with a small bubble of vapor present have been made on 10 motor gasolines over a considerable temperature range. Log p, $1/T$ plots of these data were found to be linear in the case of all the fuels within 1 to 2 mm. on the average, p representing the pressure and T the absolute temperature. The normal bubble-points ($p = 760$ mm.) of the 10 gasolines were shown to be equal to the 10-per cent A.S.T.M. temperatures, corrected for loss, within the accuracy of determining the latter. Initial liquid temperatures in the A.S.T.M. distillation were also found to be equal to the 10-per cent A.S.T.M. vapor temperatures and to the normal bubble-points obtained from the vapor-pressure data.

A general correlation of the measurements on the 10 gasolines indicated the possibility of computing all of the data by means of a single equation from either the normal bubble-point or the 10-per cent A.S.T.M. temperature. Although 10 gasolines only were employed in the work, their diversity makes it reasonable to assume that the vapor-pressure data on any commercial motor gasoline, freed from water and dissolved gases, can be computed from the 10-per cent A.S.T.M. temperature with considerable accuracy. Appendix 1 describes a vapor pressure-temperature chart.

ONE of the major purposes of the experimental work on fuel volatility at the Bureau of Standards during the last few years has been to secure for the automotive and the petroleum industries complete volatility information on typical motor gasolines. Investigations previously reported have resulted in the formulation of simple practical methods for obtaining data on complete volatility[5], represented by dew-points, and on partial volatility[6] covering the range from 10 per cent to 90 per cent evaporated. These two phases of the volatility work left a gap at the lower end of the curves, from 10 per cent to 0 per cent evaporated, and the method adopted for investigating this range involved measurements of vapor pressures and determinations of the molecular weights of the vapors. The present report deals specifically with that part of the program involving the vapor-pressure measurements.

Since the vapor pressure of a gasoline is very sensitive to changes in composition, the question of what constitutes gasoline is of importance. Commercial gasoline is a highly complex mixture ordinarily containing dissolved water, dissolved gases from the air, dissolved hydrocarbon gases having 1 and 2 carbon atoms, and a small amount of some sulphur and oxygen compounds in addition to a great variety of hydrocarbons having 3 to 10 or more carbon atoms. Hence, for vapor-pressure data on gasolines to be significant, it is essential that as specific information as possible be given on the methods used in preparing the samples for the experimental observations. If it is desirable to remove one or more constituents, their removal should be effected under reproducible conditions which eliminate only those particular compounds without changing the relative proportions of the remaining constituents.

Further, since gasoline is so complex, the decrease in vapor pressure with increase in the amount evaporated is very marked, in contrast with one-component systems, like water, where the vapor pressure is independent of the volume of vapor space. For example, with a United States motor gasoline freed from water and dissolved gases, the vapor pressure at 80 deg. cent. (176 deg. fahr.), with a small bubble of vapor present, is about 760 mm. [All pressures in this report are given in millimeters of mercury.] At the same temperature, but with sufficient vapor space to permit all of the liquid except a small drop to evaporate, the vapor pressure would be about 30 mm., representing a 25-fold change. The reason for this change lies in the fact that the vapor pressure of a composite liquid is determined by the proportions of the various constituents present in the liquid phase. The more volatile constituents have a greater tendency to go into the vapor phase; so that, on evaporation, the residual liquid becomes less volatile and hence the vapor pressure tends to decrease.

Thus, at each temperature, there will be a different value of the vapor pressure corresponding to every percentage evaporated. Therefore, for precision, it is necessary to know and specify both the temperature and the percentage evaporated, or some equivalent variable. Further, since the liquid composition changes with evaporation, it will in general be different at every percentage evaporated along a line of constant temperature, and at every temperature along a line of constant percentage evaporated. In every such case, the composition of the residual liquid will differ from that of the original gasoline. In the one special case where the

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[4] Scientific aide, Bureau of Standards, City of Washington.

[5] See S.A.E. Journal, November, 1928, p. 478.

[6] See S.A.E. Journal, April, 1928, p. 437; see also S.A.E. Journal, November, 1928, p. 478, Appendix 2.

percentage evaporated is extremely small, the composition of the gasoline will not change by more than minute amounts with temperature, and at any point will not differ essentially from that of the original gasoline transferred into the vapor-pressure apparatus.

In the present work, water and dissolved gases were removed from the fuels, and the vapor-pressure measurements were made with a very small bubble of vapor present. Hence, when the term "vapor pressure" is used subsequently in this report, it is understood that the percentage evaporated is restricted to such a small value that any decrease in the percentage would not change the pressure appreciably. While this restriction was accurately realized in the work herein reported, this is only approximately true in the case of most of the data reported in the literature, briefly discussed herewith.

Previous Work

Considerable work has been done on the vapor pressures of gasolines and a variety of methods have been developed. In general, they can be divided into three classes; (*a*) those involving direct measurement of vapor pressure, (*b*) those involving indirect measurement to correct for some one or more constituents present in the gasoline, and (*c*) those involving computation of the vapor pressure from the results of chemical analyses. In discussing these methods, the ones designed primarily for commercial purposes will not be considered since, in general, they are not more accurate than from 15 to 25 mm. A comprehensive discussion of their advantages and disadvantages has recently been given by Oberfell, Alden and Hepp[7].

Among those who measured vapor pressures directly are Wilson and Barnard[8], Rhodes and McConnell[9], Lewis[10] and Brown[11]. Air was removed by venting in every case, with consequent loss of unknown amounts of the lighter hydrocarbons. Sufficient attention was not paid to the necessity for minimizing the value of vapor space, and it seems doubtful whether adequate temperature-control was provided in all cases. Rhodes and McConnell gave a few curves illustrating the effect of air on the vapor pressure. Lewis removed water from the gasolines by means of phosphorus pentoxide.

Indirect methods were employed by Tizard and Marshall[12], by Cadman[13], by Oberfell, Alden and Hepp[14] and by Brown[15]. The first two sets of investigators used essentially the same principle, dependent upon the addition of various amounts of liquid to a given total volume. Suitable treatment of the data was designed to eliminate the effect caused by air in the apparatus, the effect of dissolved gases and the effect of changing composition with vaporization. The method of Oberfell, Alden and Hepp, employing two volumes of vapor space, is a semi-commercial method and is not adequate for precise measurements. The gasoline was saturated with water before each determination, so that correction to vapor pressures on a dry basis could be made by using the vapor pressure of water at the temperature of test. The later method adopted by Brown, depending upon the use of several vapor volumes at each temperature and upon extrapolation to zero vapor space, is excellent. He made measurements on the original gasolines containing both water and dissolved gases, and the method is capable of giving accurate vapor-pressure data on such gasolines. The procedure used to compute these data to a gas-free basis is, however, rather questionable.

The computation of vapor-pressure values on the basis of fractional analysis has been used extensively by Oberfell, Alden and Hepp[16] and recently by Brown[17]. The limitations of the methods of analysis and the unknown departures from the laws of ideal solutions tend to throw some doubt on the accuracy of such values.

General Discussion of Methods

From the theoretical viewpoint, the vapor-pressure data could be obtained by determining the pressure, at each constant temperature, at which a bubble of vapor would just form or at which the bubble would just disappear. Conceivably also, the temperature, at each constant pressure, might be determined at which the bubble would just form or just disappear. The practical objection to either method involving observation of bubble formation is that superheating almost invariably occurs and is irregular. The amount of superheating may become as high as 10 deg. cent. (18 deg. fahr.), depending upon the smoothness of the surface of the container and the degree of freedom from dust particles in the gasoline.

Determination of the temperature at which a bubble disappears at constant pressure is also open to objection, since the temperature would have to be decreased by very minute steps to permit sufficient time for the establishment of equilibrium. On the other hand, the determination of the pressure at which a bubble disappears at constant temperature seems to constitute a satisfactory method, for the pressure could be adjusted so as to maintain a sufficiently small bubble at essentially constant size for a period of time sufficient for the establishment of equilibrium. If the bubble were small enough, a pressure increase of 1 to 2 mm. would then cause its immediate disappearance. This is the method which was used in the following work.

Another method would be to measure, at each constant temperature, the vapor pressures with various volumes of vapor space and extrapolate to zero volume. This method was employed in the preliminary work, but it is very time-consuming because of the increasing length of time required for reaching equilibrium as the volume of vapor space increases. Its use was discontinued when it was found that the extrapolated values agreed to within 1 to 2 mm. with the data obtained by the small-bubble method.

The temperature at which the vapor pressure, as previously defined, becomes equal to one standard atmosphere is a characteristic property of a gasoline and is

[7] See *Bulletin of the American Petroleum Institute,* Jan. 31, 1928, p. 106.

[8] See *Industrial and Engineering Chemistry,* vol. 13, 1921, p. 906.

[9] See *Industrial and Engineering Chemistry,* vol. 15, 1923, p. 1273.

[10] See *Journal of the Institute of Petroleum Technologists,* vol. 11, 1925, p. 152.

[11] See University of Michigan Engineering Research Bulletin, No. 7, 1927.

[12] See *Journal of the Institute of Petroleum Technologists,* vol. 8, 1922, p. 217.

[13] See *Journal of the Institute of Petroleum Technologists,* vol. 10, 1924, p. 947.

[14] See *National Petroleum News,* May 16, 1928, p. 57.

[15] See Proceedings of Seventh Annual Convention of the Natural Gasoline Association of America, 1928, p. 80.

[16] See *Bulletin of the American Petroleum Institute,* Jan. 31, 1928, p. 106; see also *National Petroleum News,* May 16, 1928, p. 57.

[17] See Proceedings of Seventh Annual Convention of the Natural Gasoline Association of America, 1928, p. 80.

designated in this report as the normal bubble-point, NBP. It will be used in connection with vapor pressures in the same capacity as the normal dew-point was used in connection with the dew-point data.

In the case of a substance containing only one component, the normal bubble-point and normal dew-point are identical, and this temperature is commonly called the normal boiling-point. With a gasoline, the normal bubble-point and normal dew-point may differ from 50 to 100 deg. cent. (90 to 180 deg. fahr.). The normal bubble-point can be determined most conveniently by interpolation or extrapolation from the vapor-pressure data over a range of temperatures, and this was the main method employed. A secondary method used is dependent upon the fact that in the A.S.T.M. distillation the initial liquid temperature, corrected for loss, is equal to the normal bubble-point, within experimental error. This is illustrated in Fig. 1, where the lower dotted line is the A.S.T.M. distillation curve, obtained in the usual manner; the upper dotted line is an A.S.T.M. distillation curve with the thermometer in the liquid. The identical procedure applies to both distillations with the sole exception that vapor temperatures are read in one case and liquid temperatures in the other. Both curves are corrected for distillation loss. The solid line is the corresponding distillation curve under equilibrium conditions.

Preparation of Samples

Answer to the question whether water and dissolved gases should be removed from gasoline before making vapor-pressure measurements depends somewhat on the purpose for which vapor-pressure data are desired. Since the results obtained with the Sligh equilibrium air-distillation apparatus above 10 per cent evaporated were not appreciably affected by the presence of these constituents, which have a marked effect on vapor pressures, it seemed most consistent to make measurements on dry gas-free gasolines. Such data would be more directly comparable with engine-starting conditions, since water and dissolved gases have no appreciable effect in the engine after the gasoline has passed into

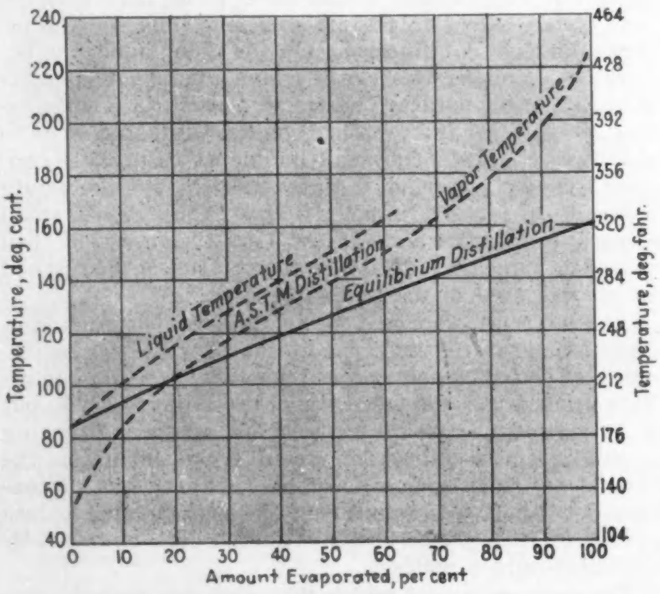

FIG. 1—DISTILLATION CURVES FOR A TYPICAL MOTOR-GASOLINE

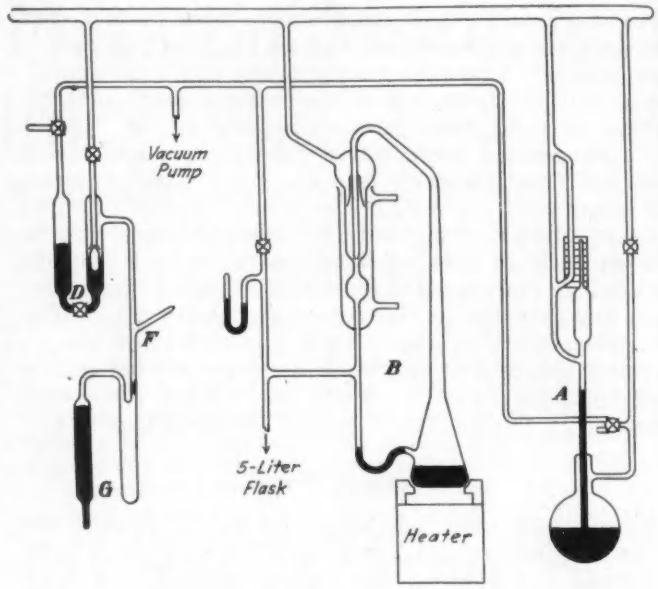

FIG. 2—APPARATUS FOR REMOVING DISSOLVED GASES FROM GASOLINES

the inlet manifold, on account of the small percentages of these constituents present.

Removal of water from each gasoline sample was effected by shaking it with phosphorus pentoxide, after which a portion of the gasoline was transferred to the apparatus for the removal of dissolved gases. The principle of the method employed in this process is based on the differences in partial pressures of the various constituents at liquid-air temperatures. Gases which might be present in quantities other than mere traces are oxygen, nitrogen, argon, methane, ethane, ethylene, acetylene and carbon dioxide. For the present purpose, hydrocarbons with 3 carbon atoms were not considered in the category of dissolved gases.

At liquid-air temperatures, oxygen, nitrogen and argon have vapor pressures of approximately one atmosphere; methane has a vapor pressure of about 70 to 20 mm., depending upon the composition of the liquid air; ethane, ethylene and carbon dioxide have vapor pressures around 0.1 mm.; and acetylene exerts a pressure intermediate between those of methane and ethane. Under the same conditions, the vapor pressure of propane above the frozen gasoline is around 0.001 mm., while that of the other constituents is negligible. Hence, efficient and repeated pumping of the frozen samples at liquid-air temperatures permits a separation of the dissolved gases from the liquid hydrocarbons. It is possible that some propane was lost, but the amount carried off probably was inappreciable.

Apparatus and Procedure

The apparatus used for removing the gases is shown in Fig. 2. About 10 ml. of gasoline was introduced into the right arm of the inverted U-tube *G* through the side tube *F*, which was then closed temporarily with a stopper. The gasoline was frozen with liquid air and the side tube *F* was sealed. The residual air above the frozen gasoline was then pumped off through the opened mercury valve *D* by means of a two-stage mercury diffusion-pump *B*, backed by a rotary-gear vacuum-pump. The vacuum attained was read on the McLeod gage *A*,

which was capable of detecting pressures as low as 0.0001 mm. of mercury. When the pressure in the system was reduced below 0.001 mm., the valve *D* was closed, the liquid-air container was removed from *G*, and the gasoline was allowed to warm up approximately to room temperature. During the warming, a steady evolution of gas and vapor occurred. The gasoline was again frozen in liquid air, time was allowed for the hydrocarbon vapors to condense, and the system was again pumped to a pressure of 0.001 mm.

In all subsequent evacuations the system was pumped until the reading on the McLeod gage was 0.0001 mm. This cycle of operations of warming, freezing and pumping was continued until the residual pressure after freezing and before pumping was reduced to 0.0015 mm. When this stage was reached, the gases were considered to have been removed. After pumping, the U-tube was sealed off at the constriction and inverted so that the sample was enclosed above the surface of the mercury which ran in from the left arm. The gasoline was permitted to warm up and the tip on the left arm of *G* was broken, thereby subjecting the gasoline to atmospheric pressure. Ordinarily, the rate of disappearance of the vapor phase was practically instantaneous. The U-tube was then ready for attachment to a manometer for the vapor-pressure measurements.

In the preliminary work on removal of gases, the gasoline was distilled back and forth from one bulb to another, with subsequent freezing in liquid air and pumping after each distillation. Usually, four to six distillations were sufficient to remove the gases; but the time varied from 1 to 3 days, on account of the difficulty in distilling all of the heavier ends from one bulb to the other each time. In the final method just described, eight to twelve cycles of operations were necessary; but the time was reduced to from 6 to 8 hr., which made possible the preparation of a new sample each day, with the exception of benzene blends. The benzene blends took about twice as long, probably due to the occlusion of gases by the benzene crystals, which did not melt until the gasoline had warmed up to a temperature around 0 deg. cent. (32 deg. fahr.). Under these conditions, the vapor pressure of the gasoline had risen high enough to inhibit the removal of the occluded gas from the sample.

Vigorous evolution of gas and vapor occurred with most gasolines the first time the sample was allowed to warm up, and on this occasion the residual pressure after freezing was 20 to 30 mm. of mercury. With each successive cycle, the evolution of gas was less vigorous and the residual pressure dropped off very rapidly. During the last few cycles, it was necessary to warm the tube with the hand to effect bubbling.

In freezing the gasoline samples, a thin brass test-tube was placed around the glass bulb as a precautionary measure before immersion of the bulb in liquid air so that, if the glass should break, the gasoline would not come into direct contact with the liquid air. The use of the mercury valve *D* is advantageous, since it permits the gasoline to be handled without the vapors coming into contact with a stop-cock lubricant. Another precaution adopted was the heating, under a vacuum, of the mercury in the inverted U-tube *G* before the introduction of the gasoline, to remove trapped air which might otherwise come off during the process of removing the dissolved gases from the gasoline. The use of the U-tube is very advantageous, since it permits the samples to be stored without danger of evaporation and makes available a supply of samples with known vapor-pressure characteristics for possible extension of the work.

Measurement of Vapor Pressures

The apparatus used for the vapor-pressure measurements is shown in Fig. 3, where the U-tube containing the gasoline sample is represented in position at *G*. The surfaces of the mercury could be illuminated by the small electric lamp *D*, and their position with respect to a graduated scale could be read by means of the periscope *E*. The bath was filled with water for the work at higher temperatures, and with a non-flammable mixture of carbon tetrachloride and chloroform for the lower temperatures. Regulation of the temperature to better than 0.1 deg. cent. (0.2 deg. fahr.) could be effected for

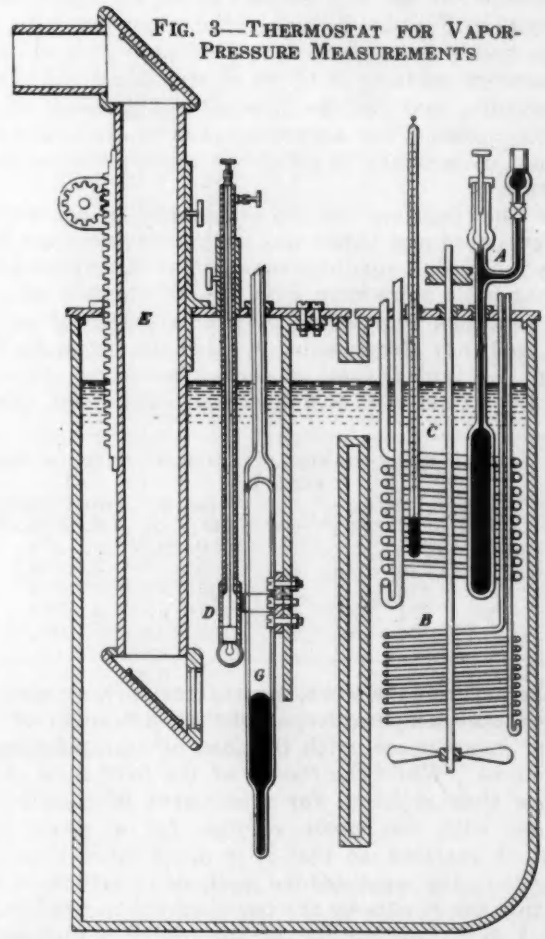

Fig. 3—Thermostat for Vapor-Pressure Measurements

indefinite periods by means of the mercury-in-glass thermo-regulator *A*, which controlled the heat input from the electric heater *B*. For low-temperature work, the carbon-dioxide expansion-coil *C* could be used. Temperatures were read by means of a calibrated mercury thermometer.

A schematic diagram of the U-tube *G* attached to the manometer *I* is shown in Fig. 4. The three-way stopcock *H* was used to adjust the transmitting air-pressure between the mercury surfaces in the U-tube and in the manometer, by connection either to the vacuum line or to the atmosphere. In making a measurement, the temperature of the thermostated bath was adjusted to the desired value, and the pressure on the gasoline was re-

duced through H until vapor formed. It was ordinarily necessary to reduce the pressure considerably below that exerted at equilibrium. The result was that a fairly large amount of vapor would form almost spontaneously, necessitating careful manipulation to avoid losing a portion of the sample. As soon as the vapor phase appeared, rapid adjustment of the pressure was made until a very small bubble remained. Readings of the mercury manometer were then begun and, from time to time, minor adjustments in pressure were made to keep the bubble from growing larger or disappearing entirely. Pressure readings were taken until constancy to 1 mm. was attained, after which the temperature was adjusted to another value and the process was repeated. The difference in level of the mercury surfaces in the manometer gave, directly in millimeters of mercury, the pressure on the mercury surface in the right arm of the U-tube G in Fig. 4. To obtain the vapor pressure, correction had to be made for the difference in level of the two mercury surfaces in G, which was measured at each temperature, and for the hydrostatic pressure of the gasoline. This latter correction was of the order of 3 to 4 mm. of mercury in all of the vapor-pressure measurements.

The time required for the attainment of equilibrium between liquid and vapor was ordinarily less than 1 hr. It was found that readings taken after that interval did not change by more than 1 or 2 mm. On several occasions, readings were extended over a period of several hours, and they always substantiated the foregoing conclusion. A typical case of such a series is shown in Table 1 for Fuel V at 40.0 deg. cent. (104.0 deg. fahr.).

TABLE 1—TIME REQUIRED FOR ATTAINMENT OF EQUILIBRIUM, FUEL V

Time, Hr.	Vapor Pressure, MM. of Mercury	Time, Hr.	Vapor Pressure, MM. of Mercury
0.5	273	4.0	274
1.0	274	5.0	274
1.5	274	6.0	273
2.0	274	7.0	273
3.0	274	7.5	274

In the preliminary work, measurements were made at each constant temperature, employing a number of volumes of vapor space, with the idea of extrapolating to zero volume. While the theory of the method is excellent, the time required for attainment of equilibrium increases with the vapor volume, for a given total amount of gasoline, so that it is much more time-consuming than the small-bubble method. Further, it was found that the results by the two methods were identical within 1 to 2 mm.; therefore, the use of a number of volumes was discontinued. The agreement of the results by the two methods indicates that the size of the bubble used, about 0.04 ml., was sufficiently small so that decrease in its size would not increase the pressure by more than 1 to 2 mm. It was also found experimentally, at least once with each sample, that increase in pressure by this amount would cause the bubble to disappear. This size of bubble is equivalent to a value of 0.004 for the ratio of the vapor volume to that of the liquid, or equivalent to about 0.002 per cent evaporated.

Vapor-Pressure Data

The general procedure adopted was to obtain vapor-pressure values at a sufficient number of temperatures to cover the desired pressure range. To test the consistency of the data on each gasoline, the logarithms of the vapor pressures were plotted against the reciprocals of the temperatures on the Kelvin scale; that is, centigrade temperatures plus 273.1. Such a plot is shown

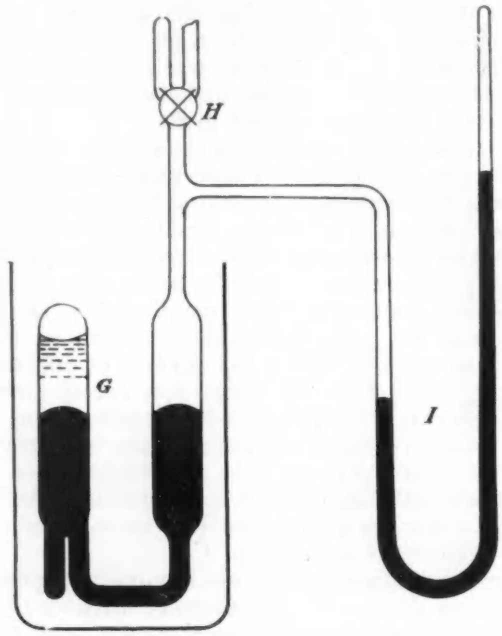

FIG. 4—SCHEMATIC SET-UP FOR MEASUREMENT OF VAPOR PRESSURE

in Fig. 5 for fuel B_2. It is to be noted that a straight line through the points reproduces the value within experimental error. The equation for this line is of the form

$$\log p = a - (b/T) \qquad (1)$$

where a and b are constants to be evaluated from the experimental data or from the plot. Equations of this type were found to reproduce the measurements on each gasoline.

Vapor-pressure data were obtained on 10 gasolines,

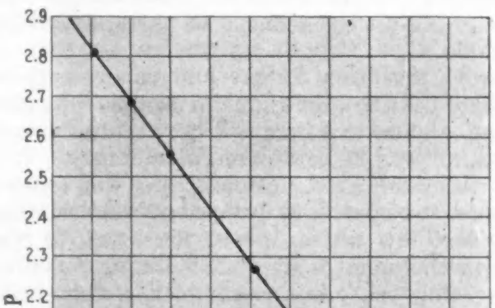

FIG. 5—VAPOR-PRESSURE LINE FOR FUEL B_2

which are described in Table 2 along with some other fuels used in the determination of the normal bubble-points. The specification data on all of these fuels are shown in Table 3. Gasolines used in the vapor-pressure work are marked with an asterisk in both tables. These include one domestic aviation-gasoline, one United States motor-gasoline, two Russian naphthas, two benzol blends and one blend with cleaners' naphtha. The original vapor-pressure data for the 10 gasolines are shown in

TABLE 2—DESCRIPTION OF GASOLINE SAMPLES

Fuel Sample	Source	Remarks
A	Bureau of Standards	1927 current supply of United States motor
*S**	Bureau of Standards	1928 current supply of United States motor
B, B_2*	Army Air Corps	Domestic aviation
C, C_2		Blend, 50 per cent of *A* and 50 per cent of *B*
*D**	The Texas Co.	
E_2*	The Texas Co.	Special blends for acceleration work
F	The Texas Co.	
L	Standard Oil Co. of N. J.	Laurel Oil
*RH**	Vacuum Oil Co.	Russian naphthas, Grozny crude
*RL**	Vacuum Oil Co.	Russian naphthas, Grozny crude
*R**		Blend of residues
*T**		Blend, 80 per cent of *S* and 20 per cent of chemically pure benzene
*U**		Blend, 60 per cent of *S* and 40 per cent of chemically pure benzene
*V**		Blend, 80 per cent of *S* and 20 per cent of cleaners' naphtha
BT		Blend, 50 per cent of chemically pure benzene and 50 per cent of chemically pure toluene

*Gasolines on which vapor-pressure measurements were made.

Table 4. The calculated pressures were computed from equation (1), using the appropriate values of a and b which are shown in the last two columns respectively. The general agreement between observed and calculated values is good, the grand average deviation from linearity of log p, $1/T$ lines being about 1 mm. of mercury.

The normal bubble-point of each gasoline was computed from the vapor-pressure equation (1), using the constants given in Table 4. A comparison of these tem-

TABLE 4—VAPOR-PRESSURE DATA ON 10 GASOLINES

Fuel Sample	Temperature Deg. Cent.	Temperature Deg. Fahr.	Vapor Pressure MM. of Mercury Observed	Vapor Pressure MM. of Mercury Calculated	△	Average △	a	b
B_2	—19.7	—3.5	35	36	—1	0.8	6.851	1,343
	0.0	32.0	86	86	0			
	19.5	67.1	184	183	1			
	39.4	102.9	358	357	1			
	49.4	120.9	487	486	1			
	59.4	138.9	646	647	—1			
D	0.0	32.0	38	41	—3	1.0	6.735	1,399
	19.5	67.1	90	90	0			
	39.4	102.9	181	181	0			
	59.4	138.9	337	336	1			
	79.6	175.3	586	585	1			
E_2	0.0	32.0	41	42	—1	2.4	6.789	1,409
	19.5	67.1	94	94	0			
	39.4	102.9	193	191	2			
	59.4	138.9	363	357	6			
	79.6	175.3	618	621	—3			
RH	—9.8	14.4	26	26	0	0.4	6.884	1,438
	0.0	32.0	41	41	0			
	29.4	84.9	136	135	1			
	49.4	120.9	266	266	0			
	69.5	157.1	483	484	—1			
RL	—19.7	—3.5	36	37	—1	1.0	6.720	1,307
	0.0	32.0	85	85	0			
	29.4	84.9	253	251	2			
	49.4	120.9	464	464	0			
	67.5	153.5	762	760	2			
R	0.0	32.0	30	29	1	1.0	6.707	1,424
	29.4	84.9	101	100	1			
	49.4	120.9	194	195	—1			
	69.5	157.1	355	353	2			
	90.0	194.0	610	610	0			
S	—19.7	—3.5	38	38	0	2.4	6.625	1,278
	0.0	32.0	87	89	—2			
	19.5	67.1	184	180	4			
	39.4	102.9	345	342	3			
	59.4	138.9	604	607	—3			
T	0.0	32.0	71	72	—1	1.0	6.894	1,376
	19.5	67.1	157	156	1			
	39.4	102.9	311	311	0			
	59.4	138.9	567	569	2			
U	0.0	32.0	72	71	1	2.0	6.850	1,365
	19.5	67.1	152	153	—1			
	39.4	102.9	307	304	3			
	59.4	138.9	553	556	—3			
V	0.0	32.0	68	70	—2	2.4	6.546	1,284
	19.5	67.1	144	144	0			
	39.4	102.9	274	274	0			
	59.4	138.9	488	484	4			
	79.6	175.3	799	805	—6			

Grand Average Deviation = 1.3 mm.

TABLE 3—SPECIFICATION DATA FOR GASOLINES

Fuel Sample	Initial Boiling-Point Deg. Cent.	Initial Boiling-Point Deg. Fahr.	20 Per Cent Deg. Cent.	20 Per Cent Deg. Fahr.	50 Per Cent Deg. Cent.	50 Per Cent Deg. Fahr.	90 Per Cent Deg. Cent.	90 Per Cent Deg. Fahr.	End-Point Deg. Cent.	End-Point Deg. Fahr.	60 Deg./60 Deg. Specific Gravity	Loss, Per Cent	Residue, Per Cent
A	38	100	100	212	136	277	199	390	220	428	0.768	1.2	1.3
*S**	40	104	93	199	139	282	198	388	221	430	0.749	1.7	1.4
B	32	90	80	176	102	216	136	277	155	311	0.714	2.0	1.0
B_2*	36	97	81	179	103	217	136	275	156	313	0.716	1.5	1.3
C	36	97	87	189	116	241	178	352	215	419	0.741	1.2	1.3
C_2	41	106	90	194	119	246	181	358	210	410	0.745	1.5	1.5
*D**	48	118	103	217	122	252	204	399	227	441	0.754	0.8	1.2
E_2*	50	122	109	228	142	288	204	399	226	439	0.761	1.9	1.3
F	43	109	103	217	164	327	199	390	223	433	0.766	1.0	1.0
L	112	234	118	244	126	259	152	306	180	356	0.751	0.3	1.2
*RH**	51	124	99	210	126	259	169	336	204	398	0.739	0.5	1.1
*RL**	46	115	84	183	105	221	148	298	188	370	0.724	0.3	1.2
*R**	61	142	104	219	144	291	203	397	227	441	0.766	1.0	1.0
*T**	44	111	83	181	112	234	191	376	219	426	0.772	1.5	1.4
*U**	51	124	80	176	92	198	185	365	213	415	0.797	1.4	1.4
*V**	43	109	107	225	150	302	197	387	219	426	0.756	1.5	1.2

*Gasolines on which vapor-pressure measurements were made.

TABLE 5—COMPARISON OF NORMAL BUBBLE-POINTS BY VAPOR-PRESSURE METHOD WITH 10-PER CENT A.S.T.M. TEMPERATURES

Fuel Sample	Normal Bubble-Point Deg. Cent.	Normal Bubble-Point Deg. Fahr.	10-Per Cent A.S.T.M. Point Deg. Cent.	10-Per Cent A.S.T.M. Point Deg. Fahr.	Ratio[18]
B_2	65.3	149.5	67	153	1.005
D	90.0	194.0	91	196	1.003
E_2	87.5	189.5	86	187	0.996
RH	86.0	186.8	85	185	0.997
RL	67.7	153.9	71	160	1.009
R	99.1	210.4	98	208	0.997
S	68.0	154.4	68	154	1.000
T	69.7	157.5	70	158	1.001
U	71.0	159.8	73	163	1.006
V	77.2	171.0	78	172	1.002
				Average Ratio	1.001
				Average △	0.003

[18] $T_{10 \text{ Per Cent A.S.T.M.}}$; T_{NBP}

peratures with the 5, 10 and 15-per cent A.S.T.M. points, corrected for loss, indicated that a satisfactory relation could be obtained between the normal bubble-points and the 10-per cent points, but that the relation to the other A.S.T.M. points was less satisfactory. The comparison of the normal bubble-points with the 10-per cent A.S.T.M. points, corrected for loss, is made in Table 5 for the 10 fuels. The ratio of the temperatures, expressed in absolute degrees, is very constant and is so close to unity that the two temperatures can be considered as equal. The average deviation of 0.003 in the ratio is equivalent to an average temperature-deviation of 1.2 deg. cent. (2.2 deg. fahr.), which is about the accuracy with which the 10-per cent A.S.T.M. temperature is reproducible. The analogous average deviations using the 5-per cent and the 15-per cent A.S.T.M. points, corrected for loss, were respectively 3 deg. cent. (5 deg. fahr.) and 2 deg. cent. (4 deg. fahr.). Thus it appears that the use of the 10-per cent point gives an agreement among the values for the individual gasolines about two to three times better than does the use of either the 15-per cent or the 5-per cent temperatures.

Normal Bubble-Points by Boiling-Point Method

The normal bubble-point is the temperature at which bubbles will start to form in a gas-free gasoline at atmospheric pressure. Hence, if such a gasoline were heated in a flask open to the atmosphere, the initial liquid temperature at which bubbles formed would be the normal bubble-point if superheating could be prevented. In the A.S.T.M. distillation the gasoline rapidly becomes gas-free, and this evolution of gas is rather effective in preventing superheating; so, a number of distillation experiments were made with a thermometer in the liquid in addition to the one placed in the normal position. The standard A.S.T.M. procedure was adopted and, every time the vapor temperature was read, the reading of the thermometer in the liquid was noted. After about 50 per cent of the gasoline had distilled off, the liquid-temperature readings were discontinued, since insufficient liquid was present to cover the thermometer bulb. The liquid-temperature readings were plotted against the percentage evaporated, making correction for distillation loss, and the curve was extrapolated back the short distance to 0 per cent evaporated. This extrapolation of the liquid-temperature curve is feasible, for its curvature is very much less than that of the ordinary A.S.T.M. curve. In these modified distillations, the vapor temperatures did not appear to be affected by the presence of the second thermometer.

TABLE 6—COMPARISON OF NORMAL BUBBLE-POINTS BY A.S.T.M. LIQUID-TEMPERATURE AND VAPOR-TEMPERATURE METHODS

Fuel Sample	Vapor-Pressure Method Deg. Cent.	Vapor-Pressure Method Deg. Fahr.	A.S.T.M. Liquid-Temperature Method Deg. Cent.	A.S.T.M. Liquid-Temperature Method Deg. Fahr.	Difference Deg. Cent.	Difference Deg. Fahr.
B_2	65.3	149.5	66	151	—0.7	—1.5
D	90.0	194.0	92	198	—2.0	—4.0
E_2	87.5	189.5	86	187	1.5	2.5
RH	86.0	186.8	86	187	0.0	—0.2
RL	67.7	153.9	70	158	—2.3	—4.1
R	99.1	210.4	100	212	—0.9	—1.6
S	68.0	154.4	67	153	1.0	1.4
T	69.7	157.5	69	156	0.7	1.5
U	71.0	159.8	72	162	—1.0	—2.2
V	77.2	171.0	77	171	0.2	0.0
				Average △	1.1	2.0

Values of the initial liquid temperatures for a number of gasolines are given in Table 6, where a comparison is made with the normal bubble-points of the same gasolines, obtained from vapor-pressure data. The agreement is fairly good, the average difference being 1.1 deg. cent. (2.0 deg. fahr.). Determinations of the initial liquid temperatures of a number of other gasolines were made, and all of the data on normal bubble-points by this method are collected in Table 7, where a comparison is drawn with the 10-per cent A.S.T.M. vapor temperatures of these gasolines. The ratio of the absolute temperatures is essentially unity, the average deviation of 0.003 being equivalent to about 1 deg. cent. (1.8 deg. fahr.).

TABLE 7—COMPARISON OF NORMAL BUBBLE-POINTS BY THE A.S.T.M. LIQUID-TEMPERATURE METHOD WITH THE 10-PER CENT A.S.T.M. VAPOR-TEMPERATURES

Fuel Sample	Normal Bubble-Point Deg. Cent.	Normal Bubble-Point Deg. Fahr.	10-Per Cent A.S.T.M. Point Deg. Cent.	10-Per Cent A.S.T.M. Point Deg. Fahr.	Ratio[19]
B_2	66	151	67	153	1.003
D	92	198	91	196	0.997
E_2	86	187	86	187	1.000
RH	86	187	85	185	0.997
RL	70	158	71	160	1.003
R	100	212	98	208	0.994
S	67	153	68	154	1.003
T	69	156	70	158	1.003
U	72	162	73	163	1.003
V	77	171	78	172	1.003
A	73	163	74	165	1.003
B	64	147	63	145	0.997
C	72	162	72	162	1.000
C_2	72	162	73	163	1.003
F	77	171	75	167	0.994
L	117	243	117	243	1.000
BT	90	194	89	192	0.997
Toluene	109	228	108	226	0.997
				Average Ratio	1.001
				Average △	0.003

[19] $T_{10 \text{ Per Cent A.S.T.M.}}$; T_{NBP}

General Correlation of Vapor-Pressure Data

A study of the vapor-pressure data on the 10 gasolines given in Table 4 indicated the possibility of correlating all of them by means of a single analytical expression. It has been shown that the data on each gasoline could be represented accurately by means of the relation $\log p = a - (b/T)$. When $p = 760$, $T = T_{NBP}$ so that

$$\log 760 = a - (b/T_{NBP}) \tag{2}$$

Subtracting equation (2) from equation (1), there results

$$\log (p/760) = b/T_{NBP} \, [1 - (T_{NBP}/T)] \qquad (3)$$

Equation (3) can be rearranged to give

$$T_{NBP}/T = 1 - [C \log (p/760)] \qquad (4)$$

where $C = T_{NBP}/b$. Although the values of b and T_{NBP} are different for each gasoline, their ratio C might be essentially the same for all motor gasolines. If C is constant, then, at any given pressure p, the ratio T_{NBP}/T will have the same value for every gasoline.

To test the constancy of T_{NBP}/T, values of this ratio have been computed for each of the 10 gasolines at a number of different pressures, and these data are shown in Table 8. The ratios are seen to be very constant. For comparison, the average deviations in millimeters of mercury corresponding to the average deviations in the ratios are also included. The average pressure-deviations in the correlation of all the data are about five times as large as the individual deviations found in putting a similar equation through the data on any one gasoline, as illustrated previously in Table 4. It is interesting to note that the pressure deviations fall off very rapidly at low pressures, even though the average

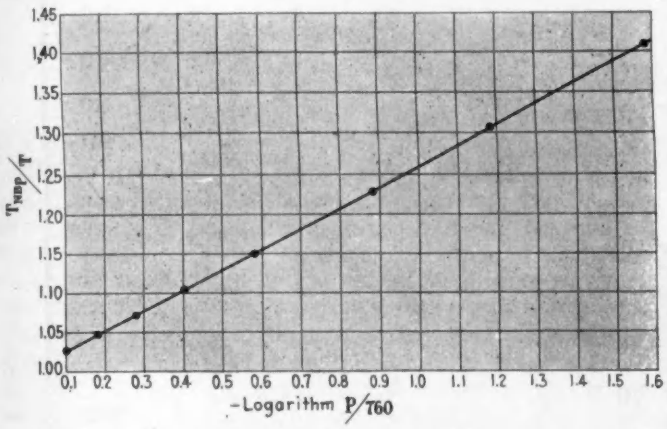

FIG. 6—GENERAL RELATION BETWEEN TEMPERATURE AND VAPOR PRESSURE OF GASOLINES

deviations in temperature ratios continue to increase. This is on account of the marked change in dp/dT as the pressure decreases.

The average temperature-ratios in Table 8 are plotted in Fig. 6 against the corresponding values of $\log (p/760)$. The equation of the straight line through the points is

$$T_{NBP}/T = 1 - 0.2578 \log (p/760) \qquad (5)$$

from which it is seen that the constant C of equation (4) is equal to 0.2578.

Although experimental data have been obtained on 10 gasolines only, it is believed that equation (5) will represent to a close approximation the vapor-pressure data on commercial motor gasolines in general, after the removal of water and dissolved gases. Since it has been shown previously that the normal bubble-point of a dry gas-free gasoline is identical with the 10-per cent A.S.T.M. temperature, corrected for loss, this latter point can be used equally well in equation (5) in place of T_{NBP}.

Two simpler methods of obtaining relation (5) are available, but it was believed that the method chosen was better adapted to illustrate the general agreement

TABLE 8—RATIO OF NORMAL BUBBLE-POINTS IN DEGREES ABSOLUTE TO TEMPERATURES IN DEGREES ABSOLUTE AT WHICH THE GASOLINES EXERT VARIOUS CONSTANT-VAPOR PRESSURES

Fuel Sample	Pressures, MM. of Mercury 600	500	400	300	200	100	50	20
B_2	1.026	1.046	1.070	1.102	1.146	1.222	1.298	1.398
D	1.027	1.047	1.072	1.105	1.150	1.229	1.307	1.410
E_2	1.026	1.047	1.071	1.103	1.148	1.225	1.302	1.404
RH	1.026	1.045	1.070	1.101	1.145	1.220	1.295	1.395
RL	1.027	1.047	1.073	1.105	1.151	1.229	1.308	1.411
R	1.027	1.048	1.073	1.106	1.152	1.230	1.309	1.413
S	1.028	1.049	1.074	1.108	1.155	1.235	1.316	1.422
T	1.026	1.045	1.070	1.101	1.145	1.219	1.295	1.394
U	1.026	1.046	1.070	1.102	1.146	1.222	1.298	1.398
V	1.028	1.050	1.076	1.110	1.158	1.240	1.322	1.431
Average Ratio	1.027	1.047	1.072	1.104	1.150	1.227	1.305	1.407
Average △	0.001	0.001	0.002	0.003	0.004	0.005	0.007	0.009
Average △, MM.	4	6	7	8	8	6	4	2

of the data. One of these methods is dependent on the fact that the values of a in the equation (1) for each gasoline are related to C of equation (4) by means of the relation

$$a - \log 760 = 1/C \qquad (6)$$

The average value of C could thus be computed by means of this relation. The other method would be to take the individual values of b in the equations (1), divide them into the absolute temperature of the normal bubble-point in each case, and average the results.

To give an idea of the vapor pressure at different temperatures of an average commercial gasoline, freed from water and dissolved gases, Table 9 has been computed for a gasoline with a 10-per cent A.S.T.M. point of 70 deg. cent. (158 deg. fahr). The values of dp/dT were obtained from equation (5) by differentiation, which leads to

$$\frac{dp}{dT} = \frac{8.94 \, T_{NBP} \, . \, p}{T^2} \qquad (7)$$

where temperatures are expressed on the Kelvin scale; that is, degrees centigrade plus 273.1.

Comparison with Previous Work

In general, no comparison with the data in the literature is possible, since adequate precautions have hitherto not been taken in removing the dissolved gases or in minimizing the volume of vapor space above the liquid gasoline. For these reasons there seem to be no published data which indicate agreement between the normal bubble-points and the 10-per cent A.S.T.M. temperatures. It is possible that the values of Lewis would show this agreement, but the A.S.T.M. data given are very meager. As would be anticipated from the methods used, the normal bubble-points obtained from

TABLE 9—VAPOR-PRESSURE DATA FOR A TYPICAL MOTOR-GASOLINE, FREED FROM WATER AND DISSOLVED GASES

Pressure, MM. of Mercury	Temperature, Deg. Cent.	Deg. Fahr.	dp/dT
760	70	158	19.8
700	67	153	18.5
600	61	142	16.5
500	54	129	14.3
400	47	117	11.9
300	37	99	9.5
200	25	77	6.9
100	6	43	3.9
50	—11	12	2.2
20	—30	—22	1.0

the work recorded in the literature are generally much higher than the 10-per cent A.S.T.M. temperatures.

There is considerable variation in the conclusions regarding the curvature of the log p, $1/T$ lines. Brown found that these lines were concave down; Wilson and Barnard, and Lewis, found them to be linear; whereas the data of Rhodes and McConnell and of Cadman can

mary of the average values of $1/C$ obtained from the data of each investigator is given below:

	Average $1/C$
Wilson and Barnard	4.42
Rhodes and McConnell	3.96
Lewis	4.58
Cadman	3.59
Brown	3.90

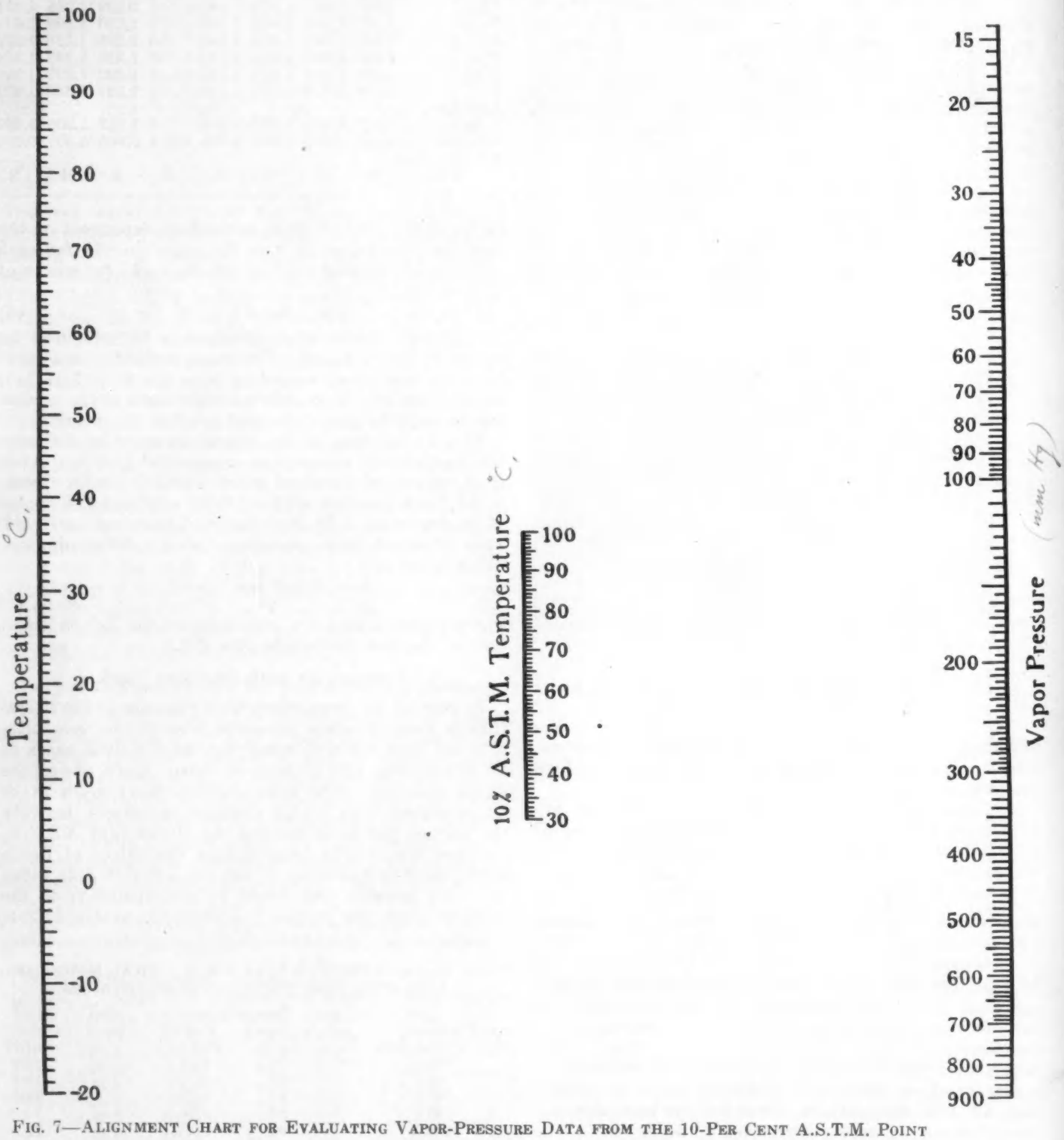

Fig. 7—Alignment Chart for Evaluating Vapor-Pressure Data from the 10-Per Cent A.S.T.M. Point

be variously interpreted. In all cases, straight lines were put through the data on each gasoline and the values of C in equation (4) were evaluated. A sum-

The agreement of the average values computed from the data of Rhodes and McConnell, and of Brown, with that obtained in the present work (3.88) is probably

fortuitous. Apparently, a compensation occurred in the effect produced by venting and the error introduced by employing a large volume of vapor space.

The relation between the vapor-pressure data and the initial liquid temperatures in the A.S.T.M. distillation is in agreement with the conclusion of Oberfell, Alden and Hepp that such a relation was valid, although no published data by them on gasolines could be found which verified their conclusions. These same investigators obtained relations between their vapor-pressure data and both the initial vapor and 5-per cent A.S.T.M. temperatures, with average deviations of about 15 to 25 mm. As noted previously, a relation to the 10-per cent A.S.T.M. temperature was found to be much more accurate.

Summary

A method and apparatus have been described for the removal of dissolved gases from dried gasolines without appreciably affecting the propane content and otherwise changing their composition. Vapor-pressure measurements with a small bubble of vapor present have been made on 10 motor gasolines over a considerable temperature range under conditions such that increase in pressure of 1 to 2 mm. would cause the bubble to disappear. Over this temperature range, the log p, $1/T$ plots of these data were found to be linear in the case of all the fuels, within 1 to 2 mm. on the average. The normal bubble-points ($p = 760$ mm.) of the 10 gasolines were shown to be equivalent to the 10-per cent A.S.T.M. temperatures corrected for loss, within the accuracy of determining the latter. Initial liquid temperatures in the A.S.T.M. distillation were also found to be equivalent to the 10-per cent A.S.T.M. vapor temperatures and to the normal bubble-points obtained from the vapor-pressure data.

A general correlation of the measurements on the 10 motor gasolines indicated the possibility of computing all the data by means of a single equation, with an average error of about 6 mm. In this equation either the normal bubble-point or the 10-per cent A.S.T.M. temperature can be employed.

Although 10 gasolines only were employed in the work, their diversity makes it reasonable to assume that the vapor-pressure data on commercial motor-gasolines, freed from water and dissolved gases, can be computed from the 10-per cent A.S.T.M. temperature with an accuracy comparable with that with which the latter temperature can be obtained.

APPENDIX I

A Vapor Pressure-Temperature Chart

The computation of vapor-pressure data from the 10-per cent A.S.T.M. distillation temperatures by means of equation (5) is somewhat inconvenient, because of the necessity for using logarithmic tables. This calculation can be obviated by the use of the alignment chart shown in Fig. 7, which permits rapid and convenient evaluation of vapor pressures at various temperatures directly from the 10-per cent A.S.T.M. point, corrected for loss, within the experimental error of the latter temperature. It should be emphasized that this chart gives the vapor pressure of the gasoline freed from water and dissolved gases, but without removal of propane or any of the more complex hydrocarbons.

The scale at the left represents the temperatures in degrees centigrade at which vapor-pressure data on the gasoline are desired. The middle scale gives the corrected 10-per cent A.S.T.M. temperatures in degrees centigrade, while the scale at the right represents vapor pressures in millimeters of mercury.

Solution of two numerical cases will illustrate the use of the chart. To find the vapor pressure at 30 deg. cent. (86 deg. fahr.) of a gasoline having a 10-per cent A.S.T.M. point of 80 deg. cent. (176 deg. fahr.), connect 30 on the scale at the left with 80 on the middle scale by means of a straight-edge and extend the line to the scale at the right. The intersection, 180 mm., is the desired vapor pressure at this temperature. If this gasoline is blended with some natural gasoline so as to reduce the 10-per cent point to 60 deg. cent. (140 deg. fahr.), a straight-edge connecting 30 on the temperature scale with 60 on the A.S.T.M. scale will show that the vapor pressure of the gasoline has been increased to 320 mm. Values for other temperatures can be obtained in a similar manner.

Highway Investment Pays Tangible Dividends

An address by the Chairman of the North Carolina Highway Commission, at Rutland, Vt., lists the returns from North Carolina's investment in good roads, totaling \$115,000,000, plus \$12,000,000 Federal aid; and claims that the investment is more than self-sustaining. The system is supported by a privilege or license fee of \$12.50 per year and up, depending upon the horsepower of the automobile, and a charge of 4 cents per gal. on motor fuel used in the operation of automobiles upon the roads. Registration of automobiles in the State in 1927 showed an increase of 11.8 per cent over 1926, against an average increase in motor car registration for the whole Country of 5.1 per cent.

Besides the generally recognized social and cultural advantages of roads, the following are pointed out: (*a*) swift and safe transportation of agricultural products by trucks is rendered possible; (*b*) good roads permit locating factories outside the congested centers and drawing their labor supply from surrounding sections; (*c*) the improved roads have made possible a public carrier system for passengers and freight covering 6,000 miles of State highway, which affords the State a direct revenue of about \$200,000 per year.—*Commerce Reports.*

Combustion Control by Cylinder-Head Design

By ROBERT N. JANEWAY[1]

DETROIT SECTION PAPER — *Illustrated with* CHARTS AND DIAGRAMS

DETONATION and shock, the two principal barriers to increased compression, are subject to a degree of control which can readily make possible the use of compression ratios in the neighborhood of 6-1 on commercial fuel without objectionable effects and without sacrifice of output.

Since detonation depends primarily upon the temperature attained by the residual unburned gas, it can be controlled by combustion-chamber design which intensifies the heat transfer from the unburned gas to the walls.

The shock tendency, which originates in the pressure-time characteristic of combustion, can be controlled only by deliberate incorporation of the desirable anti-shock characteristic in the chamber design by a method of calculation which is explained in detail. To obtain smoothness without loss of power, the volume of charge must be so distributed with respect to the firing position as to obtain as nearly as possible uniform acceleration in the rate of pressure rise up to the maximum rate, without excessive increase in the explosion time.

No definite empirical rules for chamber proportions can be laid down which will cover the wide range of variation in individual requirements. Each case calls for an independent application of the fundamental principles if maximum results are to be obtained from the design.

EVOLUTION of the automotive engine has, until comparatively recent years, been largely a process of external refinement, the working process itself having been entirely neglected. The tendency toward higher compression-ratios has introduced entirely new problems; and detonation has become the focus of attention, investigation and explanation. The resulting progress has followed two distinct directions for reducing the detonating tendency: first, by altering the fuel characteristics by means of dopes; and, second, by modification of the combustion-chamber.

The automotive industry, both here and abroad, is indebted to Mr. Ricardo for bringing about a recognition of the importance and the possibilities of combustion-chamber design. His work has stimulated further investigation and has made for real progress.

Popularization of the offset combustion-chamber for L-head engines made possible a substantial increase in compression ratio. This improvement, together with the increasing availability of antiknock fuel, removed the urgency of the detonation problem. However, the higher compression-ratios introduced a new difficulty, explosion roughness, which is often downright objectionable, especially with extremely offset chambers.

At present, combustion-chamber design has become practically standardized empirically in the form of a medium-offset type with domed contour. But, since it is of haphazard origin without any roots in an understanding of the fundamental factors involved, the results fall far short of the possibilities. In the struggle for maximum power-output, compression is invariably pushed to the ragged edge of both detonation and roughness and often into the objectionable range beyond. It may safely be said that a ratio of 5-1 to 5.25-1 represents the average maximum limit for comfort in the L-head engine using the domed offset combustion-chamber. While it is possible to avoid detonation at ratios around 6-1 by means of antiknock fuel, the consequent roughness precludes the satisfactory general use of such compression.

If further improvement is to be realized from increased compression, a rational basis must replace haphazard methods in dealing with the barriers presented by the combustion process.

Ideal Otto Cycle Not Realized

In the theoretical conception of the Otto cycle, the energy liberation is instantaneous, at constant volume, equivalent to a detonation of the entire charge. If this so-called ideal were realized, even if the engine could live, no one could live with the engine. As it is, we are approaching too close to this condition for comfort. The rate of pressure development must be controlled.

While combustion in the actual cycle is infinitely more complex than the glib assumption of the imaginary cycle, it is subject to the same universal laws as all other reactions. In these physico-chemical fundamentals we shall find a rational basis for combustion control.

Three distinct phases of the combustion process are to be dealt with; namely, (*a*) thermodynamic efficiency, (*b*) tendency to detonate, and (*c*) shock tendency. While (*b*) and (*c*) are entirely independent of each other, both are influenced by the combustion efficiency. The higher the efficiency the greater will be the tendencies to detonation and shock. But our solutions of the problems must entail no loss in efficiency.

The limiting efficiency of the actual cycle is by no means as high as theoretical consideration of the Otto cycle indicates, primarily because the actual working-medium has nothing in common with the assumed properties of the theoretical medium. Instead of being uniform, with constant specific-heat, the actual medium is one mixture during compression and another during expansion, each with its own peculiar properties. The

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differences may be boiled down to a comparison of the actual and theoretical values of the ratio of specific heats. While the theoretical air-cycle assumes a constant value of 1.4 for the adiabatic exponent, the actual mean value averages about 1.34 for compression and about 1.25 for expansion. Consequently, at a compression ratio of 5.5-1, for example, the limiting efficiency is actually 39.7 per cent, assuming no losses, instead of 49.5 per cent, as indicated by the theoretical equation. If reasonable heat-losses during expansion and compression are allowed for, the limiting cycle-efficiency at the same ratio becomes 34 per cent. Any departure from this value of indicated efficiency at 5 5-1 compression, neglecting leakage, is directly chargeable to combustion; if the indicated efficiency is 28 per cent, the corresponding combustion efficiency is 28/34, or 82.5 per cent.

The efficiency equation of the theoretical cycle is not misleading with respect to the relative gain in efficiency to be expected from increased compression-ratio; if anything, the limiting efficiency of the actual cycle shows a slightly greater relative gain from higher compression. The limiting thermodynamic-cycle efficiency is independent of load. The rapid falling-off in observed efficiencies as the load is reduced is due to friction and pumping losses, which absorb an increasing proportion of the total output, and to a decrease in combustion efficiency.

Thieves of Combustion Efficiency

Four losses affect combustion efficiency; namely, heat loss, incomplete combustion, delayed combustion or after-burning, and piston movement during combustion.

For a given mixture condition in a given engine, the heat loss during combustion depends upon the burning time, the surface of the chamber and the intensity of detonation. The effects of burning time and surface are obvious. The effect of detonation is due to a change in the radiation characteristic of the flame, apparently the result of incandescent particles of free carbon. The consequent increase in heat loss is marked and will depend upon the quantity of charge detonated.

There are definite limits to the advantage to be gained by reducing the burning time. Using a range of 20 deg. before and after top dead-center involves a piston movement of only 4 per cent of the stroke, for a ratio of connecting-rod length to stroke of 2-1, and very little loss in combustion efficiency. Because of roughness, it is desirable to prolong the burning as much as possible. Unnecessarily rapid combustion aggravates the shock tendency, with no compensating thermodynamic advantage.

The effect of turbulence in promoting flame propagation is well recognized, as is its analogous effect on the rate of all chemical reactions and many physical phenomena. Its effect on flame propagation lies in its tendency to decrease the resistance to heat transfer. In all cases of heat transfer involving a fluid medium, the coefficient of resistance to heat-flow is most sensitive to the velocity of turbulence of fluid flow; for instance, the heat-transfer coefficient of air flowing through a tube is tremendously influenced by the velocity. The rate of increase in the coefficient is greatest at low velocities and falls off as the velocity becomes greater, until a condition of saturation is approached.

Turbulence accelerates the rate of heat transfer from layer to layer of the gas during flame propagation, also, because it makes possible heat-flow by convection as well as by the slower process of conduction. Again, the effect on the explosion time is enormous in the first stages of turbulence and gradually approaches a saturated condition beyond which further increase in turbulence produces no effect, as shown by experiment.

As turbulence is produced in any engine by the high velocity of the incoming charge, it increases roughly in proportion to the speed. The residual turbulence at the time of ignition depends, in addition, upon the time available for damping, which is inversely proportional to speed. The residual turbulence therefore tends to increase as the square of the speed. Without the turbulence, the high-speed engine would be impossible; for, instead of occupying a maximum crank-angle period of 40-50 deg., combustion would require four or five times as long a period.

Maximum Power Sacrifices Economy

The effect of the combustion-chamber form in producing turbulence during the compression stroke is, at most, of minor importance. Even when the communicating area between the cylinder and the combustion-chamber is reduced to the minimum of about twice the maximum valve-opening area, the increased density of the gas during compression restricts the induced velocity to a small fraction of that obtained through the valve. For this reason it seems extremely doubtful that the chamber form can materially increase the effective turbulence. Experimental evidence points to the same conclusion.

Maximum energy liberation is incompatible with the maximum economy. It is inevitable that there will be some variation in the composition of any mixture of air, fuel and diluent; therefore, an excess of fuel must be provided to assure that each molecule of air will find a mating molecule of fuel, and an excess of air is essential to the complete combustion of the fuel content.

The relative fuel excess required for maximum output depends upon the degree of heterogeneity of the mixture. In multi-cylinder engines, the lack of uniform fuel distribution among the cylinders adds another limitation, as the fuel supplied must be enough so that the leanest cylinder will get the minimum fuel-air ratio for maximum output. The richer cylinders are thus supplied with a useless excess of fuel which is entirely wasted.

Delayed combustion or after-burning is brought about by much the same conditions which contribute to incomplete or suppressed combustion. If the variation in composition throughout the mixture is great enough, some portions of the charge may be so close to the limit of inflammability, on either the rich or the lean side, that their burning rate is relatively very slow. Thus, after complete inflammation has taken place and the major part of the charge is burned, these portions may still be burning and continue to burn throughout the expansion stroke. It follows that the greater the departure from homogeneity, the greater will be the loss from incomplete combustion and after-burning.

The portion of the heat value of the fuel which is suppressed because of incomplete combustion is a total loss. The loss due to after-burning depends upon how far it lasts into the expansion stroke. After-burning also causes higher temperatures during expansion and exhaust, resulting in increased temperatures of vital parts of the engine and greater heat-losses to be dissipated by the cooling system.

The most important factors in promoting efficient

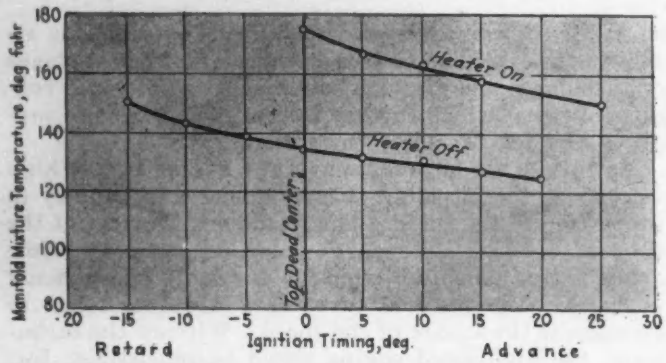


FIG. 1—TEMPERATURE OF MIXTURE IN INLET MANIFOLD

Effect of Spark Retardation, from a Test on a 4¼ x 4½-In. Six-Cylinder Engine at 1200 R.P.M. and Full Load

combustion are a high degree of turbulence, a low proportion of inert diluent, high density and temperature at ignition, and proper spark-plug location with respect to the flow of incoming charge.

Turbulence performs the function of agitation, which is so essential in obtaining a uniform mixture. For this we are primarily dependent upon intake velocity, which is largely a function of engine speed and volumetric efficiency.

Importance of Inert Gases

The presence of inert gas in the combustible mixture decreases the probability of obtaining uniform proportions of air and fuel throughout the mixture. For this reason, combustion efficiency will suffer whenever the proportion of exhaust gas is increased. Thus, low volumetric efficiency, as in part-throttle operation or at extremely high speeds, and high exhaust back-pressure, as at high speeds and loads, invariably tend to reduce combustion efficiency. The higher the compression ratio, the lower is the percentage of residual exhaust gas; and this, together with increased pressure and temperature at ignition, makes for rapid and efficient combustion.

With good mixture-condition, combustion efficiency will be little affected by the combustion-chamber design, either as to form or spark-plug location, except through the time of burning. However, when the conditions of operation produce a poor mixture-condition, the combination of the shape of the chamber and the spark-plug location, as it determines the direction of flow of the incoming charge with respect to the spark-plug, may make all the difference between efficient and inefficient combustion. At low throttle-opening—especially during idling, when the exhaust diluent becomes a major part of the mixture and turbulence is low, and at extremely high speeds, when the volumetric efficiency is low and exhaust back-pressure high and the time available for efficient combustion is extremely small—the chamber design becomes a limiting factor.

Any hesitation in the burning at high speeds is fatal to efficiency; and, if the mixture surrounding the spark-plug is on the ragged edge so that combustion is slow in starting, the exhaust valve may open in the middle of the burn. This does in fact often occur at high speeds and produces irregular operation and intermittent popping in the exhaust. This so-called high-speed miss, which occurs in many engines, has been found to be sensitive to ignition, responding, for instance, to boosting the spark by "hotter" coils, or the use of a magneto. It is well known that the hotness of the spark does not affect combustion except when the mixture is near the limit of inflammability. This observed sensitivity to ignition at high speeds is evidence of a poor mixture-condition at the spark-plug rather than of any fundamental shortcoming in the ignition system.

Late Spark Helps the Mixture

Another expedient which relieves high-speed miss is excessively retarding the spark. This considerably increases the exhaust temperature and causes higher mixture-temperatures in a hot-spotted manifold and greater heating effect from the residual burned gas in the cylinder. This improves the mixture condition and gives higher compression-temperature, which aids combustion. Also, the density of the residual gas and, consequently, its proportionate weight in the mixture are reduced. Fig. 1 shows the effect on the manifold-mixture temperature of retarding the spark, as observed on a representative six-cylinder engine, with manifold heat both on and off.

The use of magneto ignition and excessive spark-retardation certainly are not desirable methods of eliminating high-speed miss, nor are they necessary. It is possible to eliminate this evil completely by correct combustion-chamber design alone, and at the same time to obtain improvement during idle and low-load operation. To obtain a good mixture around the spark-plug, the plug should be as nearly as possible in the direct path of the intake flow through the annular passage between the valve and its seat, as illustrated at *A—A* in Fig. 2. If too close to the inlet valve or too far above it, as shown at *B—B*, the plug must depend on the fresh charge which flows over the top of the inlet valve with relatively low velocity.

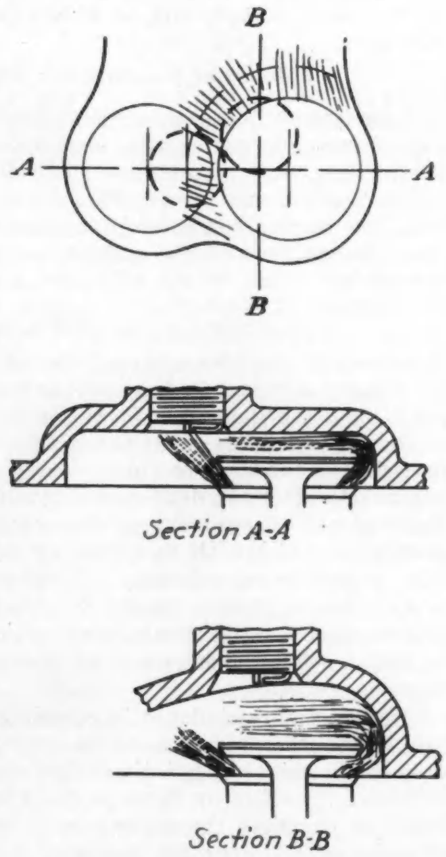


FIG. 2—LOCATION OF SPARK-PLUG

A Desirable Location with Relation to the Inlet Valve Is Shown at *A*. The Location at *B* Is Poor

The principal controllable factors, among those that affect combustion efficiency, are (*a*) fuel distribution, (*b*) pressure-time characteristic of combustion, and (*c*) spark-plug location with respect to intake flow. These

three factors hold the key to the attainment of high combustion-efficiency with smoothness of operation. The subject of distribution is outside the scope of this paper, which deals fully with the control of the pressure-time characteristic of combustion.

The mechanism of combustion is best illustrated by assuming a bomb full of combustible mixture to be divided into say 10 equal parts, as at *A* in Fig. 3, which is similar to an illustration in a paper given before the Society by Thomas Midgley, Jr., and me[2]. As burning progresses from the point of ignition, the burning gas expands and the pressure consequently increases, compressing the gas still unburned and also that previously burned, as shown by the successive diagrams in Fig. 3. Because of the high temperatures of the burned gas, the heat loss overcomes the tendency for the temperature to increase as the gas is compressed, so that the temperature remains substantially constant. Since the temperatures and rate of heat loss of the unburned gas are much lower, its compression tends to approach more nearly to the adiabatic, departure from the adiabatic depending on the effectiveness of the chamber-walls in cooling the gas.

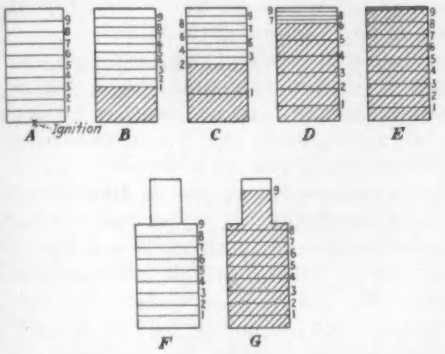


FIG. 3—COMPRESSION OF UNBURNED GAS DURING COMBUSTION

It will be observed from the diagrams of Fig. 3 that the compression of the unburned gas produces a displacement of the gas in the direction of flame movement, the rate of displacement of any particle depending upon the rate of flame travel, the location of the particle with respect to the flame front and the area of the section at the particular location. For instance, it is readily seen by comparison of diagrams *A* and *D*, Fig. 2, that a particle originally at section 6, will, before burning, move a greater distance than a particle originally at section 9 in the same length of time. However, if the sectional area of the chamber is reduced as in diagrams *F* and *G*, a particle originally at section 9 will be forced to travel a proportionately greater distance before the flame overtakes it.

Detonation Occurs at a Critical Temperature

It is evident that the temperature of the unburned gas is continually increasing during the burning, because of the compression, which is, in effect, a continuation of the compression imposed by the piston movement. Therefore, the later a particle of gas burns, the higher is its pressure and temperature when it burns. Most investigators of detonation have finally come to agree that the limiting factor is the maximum temperature attained by the residual unburned gas. This conclusion is substantiated by all observable evidence and is in entire agreement with the known laws of physical chemistry.

Detonation is a critical phase of the chemical reaction which constitutes combustion. That it is critical is proved by the comparatively minute changes which suffice to induce or suppress it, such as a few degrees difference in spark advance or an insignificant proportion of fuel dope. But the most significant thing about detonation is the fact that the entire nature of the reaction is different from that of normal combustion.

The reaction rate is infinitely greater, the luminosity and the radiation rate of the flame show marked increase[3], and ultra-violet rays are emitted which are not given off during normal combustion[4]. There is also a tendency to liberate free carbon, which perhaps accounts for the increase in luminosity and radiation. All this indicates that detonation is a reaction within a reaction; that is, when a critical condition is reached, a change occurs in the character of the fuel molecule and, consequently, in the character of the reaction itself.

It is well known that processes such as decomposition depend for their initiation on the attainment of a definite critical temperature. Thus, for each fuel that is subject to decomposition or change in molecular structure, there will be a definite critical temperature at which detonation will occur, depending to some extent on the pressure. The relative detonating tendency of various fuels, as a matter of fact, does seem to follow the stability of the fuel molecule; and such fuels as benzol and alcohol, which have very stable molecular structures, show no tendency to detonate.

How, then, does this change in the reaction characteristics produce the external effects by which we recognize detonation?

Detonation Induces a Pressure Wave

The tremendous increase in the reaction rate which is characteristic of detonation produces almost instantaneous combustion of the residual unburned gas when the critical point is reached. This means that the compression pressures of the burned and unburned gas, which remain in equilibrium during normal combustion, have no time to equalize, so that the residual gas is burning at constant volume. This results in the development of a tremendous localized pressure, thereby destroying the equilibrium that had previously existed.

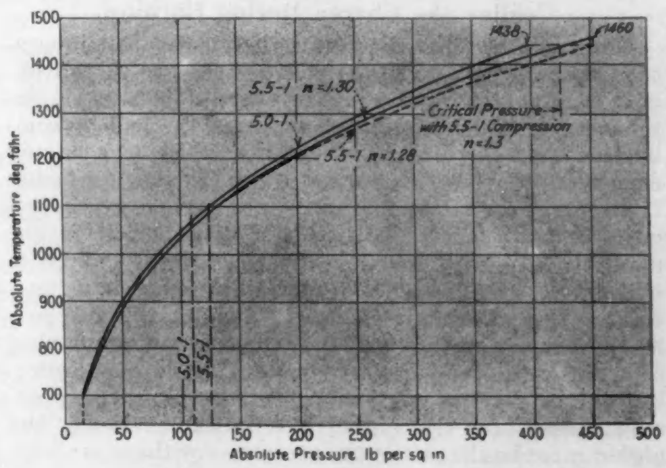


FIG. 4—EFFECT OF COMPRESSION RATIO ON THE MAXIMUM TEMPERATURE OF THE UNBURNED GAS

[2] See THE JOURNAL, April, 1923, p. 367; also TRANSACTIONS, vol. 12, 1923, part 1, p. 51.

[3] See THE JOURNAL, February, 1924, p. 182, and TRANSACTIONS, vol. 14, 1924, part 1, p. 18.

[4] See S.A.E. JOURNAL, August, 1928, p. 167.

In restoring the pressure balance, a wave is set up, the intensity of which depends upon the proportion of the charge that detonates. The localized pressure momentarily developed may be three times as great as the critical pressure, and this tremendous pressure-differential must impart a terrific velocity to the resulting wave. For this reason, the kinetic energy is so great, even when a very small part of the total charge detonates, that the impact on the walls of the chamber produces the familiar "pinking" sound. When detonation is unusually severe, the impact is often great enough to crack spark-plugs.

Since detonation necessarily occurs only in the small residual part of the charge near the end of the burn, it could not make itself felt throughout the entire body of gas unless the disturbance were transmitted by a wave motion such as has been described. An indicator element located anywhere in the chamber will receive the full force of the impact and record an apparent sharp rise in pressure. Since this record is the result of impact and not of static pressure, the indicator element immediately returns to a position corresponding to the effective maximum static pressure, and the card shows a sharp peak. The kinetic energy of the wave is rapidly dissipated into heat, raising the temperature and the static pressure to the point that would have been attained by normal combustion of the entire charge. The only loss is that due to the increased rate of heat loss occurring during detonation, and this does not become appreciable unless detonation is very severe.

The objection to detonation is not that it causes direct loss of power, nor is it merely that the knock is psychologically unpleasant. The primary danger is that, if detonation is severe and sustained for any length of time, the increased heat radiation will produce hot-spots sufficient to induce preignition. In addition, the effect on spark-plugs is highly destructive. This is illustrated by my experience with an experimental car having a 7-1 compression-ratio engine, during the early stages of ethyl-gas development. This engine called for at least 17 cc. of ethyl fluid per gallon of fuel. Through some mistake, I was obliged to drive this car from Indianapolis to Dayton, Ohio, a distance of 100 miles, without benefit of ethyl fluid. Although the job was "babied," to avoid severe detonation as much as possible, there was not a whole spark-plug left in the engine at the end of the trip.

Cooling the Charge During Burning

The variables that determine the maximum temperature of compression of the unburned gas are the initial-charge temperature and pressure at the closing of the inlet valve, the maximum pressure at the end of combustion, and the amount of cooling of the gas during compression by the piston and by the advancing flame-front. The initial temperature is governed by the requirements of fuel condition and distribution in the manifold, although excessive heating of the charge is undesirable at full load. The initial pressure is a function of the volumetric efficiency, and its effect is primarily due to the fact that the temperature rise during compression depends, not upon the absolute pressure, but on the ratio of maximum pressure to initial pressure; therefore, the higher the initial pressure, the higher must be the maximum pressure for the same temperature-rise.

The pressure or density in itself has a minor effect on the critical temperature, which tends to increase as the pressure decreases. For this reason, throttling decreases detonation only to a minor extent, as is shown by the very considerable reduction in load required to eliminate detonation by throttling, as recorded in the paper on Laws Governing Detonation[5], to which reference has been made. Curves in this paper show how, for a given initial temperature, the maximum and initial pressures both decrease with decrease in initial pressure, converging until they coincide when detonation disappears. The marked effect of initial temperature on the critical pressure is also brought out by these curves. The relative intensity of detonation depends upon the difference between the critical and maximum pressures, since this is a measure of the proportion of the charge unburned at the time of detonation.

It is evident that, with the initial temperature and pressure and the fuel given, the only controllable factor through which we can effect the critical pressure of detonation, and thus the permissible maximum pressure, is the cooling of the unburned gas as it is compressed.

Cooling during the compression stroke is important, but it is fixed by considerations of jacket-water temperature and bore-stroke ratio as it affects the ratio of cylinder surface to charge weight, which increases as the bore is decreased. We are then dependent for detonation control on the amount of cooling we can provide in the combustion-chamber to restrict the temperature of compression during combustion.

A Quantitative Illustration Given

To gain some quantitative idea of the problem, let us consider what happens when the compression ratio is increased in a given case. Suppose that, with a nominal compression-ratio of 5-1, the maximum pressure is at the critical value corresponding to borderline detonation, assumed to be 400 lb. per sq. in., abs.; that the initial pressure is 16 lb. per sq. in. and the initial temperature 700 deg. fahr., abs.; and that the exponent is 1.28 during compression by the piston and 1.30 during combustion. Then, as shown in Fig. 4, the temperature at the end of the compression stroke, corresponding to an absolute pressure of 110 lb. per sq. in., is 1068 deg. fahr., abs., and at the maximum pressure of 400 lb. per sq. in., abs., the temperature of compression of the last gas to burn is 1438 deg. fahr., abs.

If, now, the compression ratio is increased to 5.5-1, other things being the same, the initial temperature will be a little lower because of the smaller volume of residual burned gas. As calculated for this case, the temperature at inlet-valve closing will be 691 deg., instead of 700 deg. as before. Using the same exponents of compression, the temperature at the compression pres-

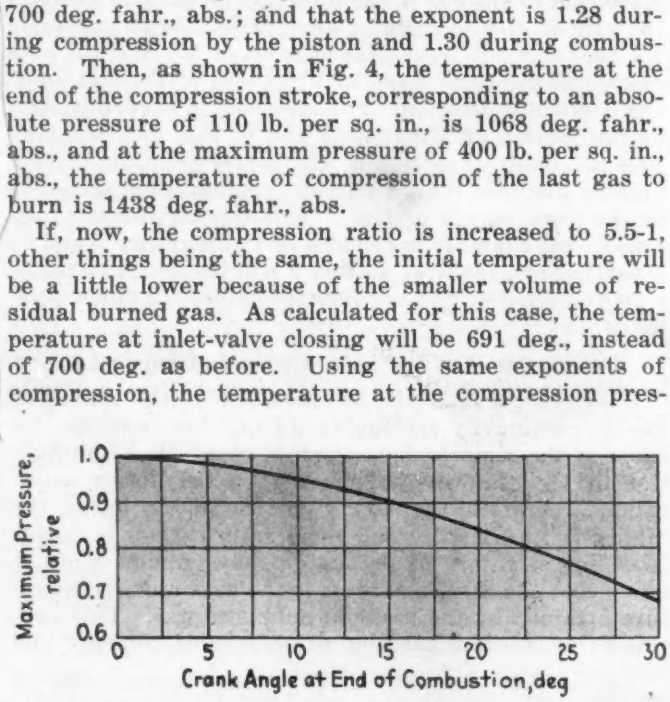


FIG. 5—EFFECT OF COMBUSTION END-POINT ON MAXIMUM PRESSURE

[5] See THE JOURNAL, April, 1923, p. 371.

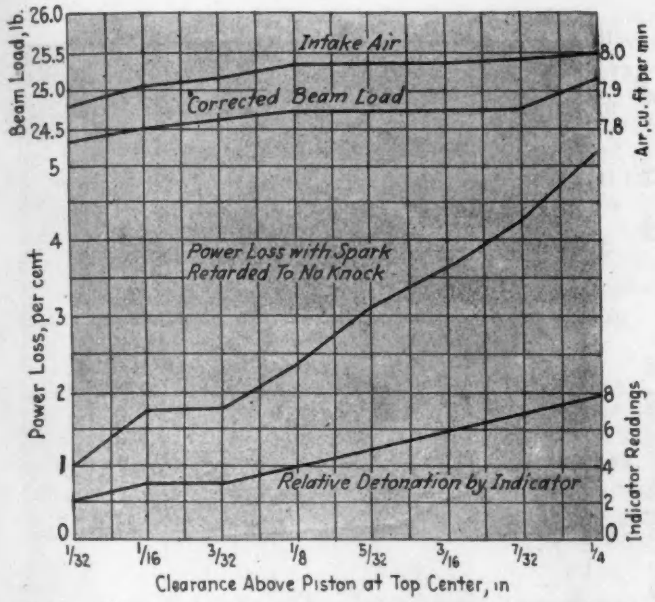


FIG. 6—VARYING THE DEPTH OF THE CLEARANCE ABOVE THE PISTON

Effect in an Offset-Chamber Cylinder-Head, Under Full-Load Conditions, with Constant Compression-Ratio, at a Speed of 1000 R.P.M.

sure of 125.5 lb. per sq. in., abs., will be 1085 deg. fahr., abs., and the maximum unburned gas temperature will be 1460 deg., corresponding to a maximum pressure of 455 lb. per sq. in., as shown in the second curve of Fig. 4. The net increase in the maximum temperature of the unburned gas is thus only about 20 deg. fahr. However, the critical temperature of detonation remaining at 1438 deg., the same as in the case of the lower compression, detonation will occur at the corresponding critical pressure of 427 lb. per sq. in., abs. The relative weight of charge already burned at this pressure will be roughly proportional to the pressure rises, (427 — 125)/(455 — 125), or 91.7 per cent. The relative weight of the charge remaining to be detonated is thus 8.3 per cent.

If, instead of following the same exponent of compression during combustion, the cooling effect is increased with the higher compression so as to lower the maximum compression-temperature to the same value as with 5-1 compression, as shown in the dotted branch of the second curve of Fig. 4, the condition will be that of borderline detonation, as at the lower compression. This example, which is representative, shows how sensitive detonation is to slight changes in temperature. In this case, the additional cooling required to lower the maximum temperature of the unburned gas 20 deg., in a total of 1000 deg. fahr., makes possible an increase in compression ratio from 5-1 to 5.5-1 without detonation.

Small Clearance Raises Critical Pressure

It is fortunate that the smaller clearance causes lower initial temperature, resulting in higher critical pressure. Otherwise, we should have to be content with considerably lower compression than we are using successfully. This is not merely a theoretical conclusion. Actual observations which I made on a variable-compression engine showed that the critical pressure invariably increases with compression ratio, other things being equal, but not so fast as the maximum pressure.

While we are dealing with actual figures, it will also be of interest to show quantitatively how spark retardation operates to reduce detonation. Later ignition causes the maximum pressure to be reached later, after greater piston-movement during expansion. Because of the resulting increase in volume before combustion is completed, the maximum pressure is reduced. Fig. 5 shows the relative variation in maximum pressure according to the crank position at which combustion is completed, calculated for a 2-1 ratio of connecting-rod length to stroke, using an expansion exponent of 1.35. To eliminate detonation by retarding the spark, in this case, it is necessary to reduce the maximum pressure from 455 lb. per sq. in. absolute to the critical value 427 lb., in the ratio of 427/455, or 0.935. If the maximum pressure of 455 lb. per sq. in. occurs at say 15 deg. after top center, the spark will have to be retarded so as to bring the combustion end-point to 20 deg. after top center, where the maximum pressure, according to Fig. 5, will be 93.5 per cent of what it was at 15 deg. Thus, in this case, a retardation of 5 deg. will reduce the maximum pressure to the critical value and eliminate detonation.

As the antiknock effect of the combustion-chamber depends on the degree of cooling which it exerts on the unburned gas during combustion, a rational basis for antiknock combustion-chamber design is to be found in the known laws of heat transfer.

In any case, the total heat transferred is a resultant of temperature difference, nature of surface, coefficient of resistance to heat transfer, and time; and the change in temperature of a given body is the total heat transferred divided by its weight and specific heat. To reduce detonation tendency efficiently, the cooling effect should be concentrated as much as possible upon the unburned gas and as little as possible upon the burned gas. Increased heat loss from the burned gas will tend to reduce detonation because of the lower maximum pressure, but only at the expense of efficiency. We shall consider each of the fundamental factors and endeavor to apply them to the problem of intensifying the heat transfer from the unburned gas to the chamber-walls.

Cooling the Unburned Gas

Since we are concerned primarily with the maximum temperature, we can study the effect of cooling surface and weight of gas to be cooled by combining them into a ratio. As the most efficient cooling is that which is concentrated on the last gas to burn, it is of advantage to provide the greatest possible ratio of surface to weight at the end of the flame travel. This effect has been achieved by the simple, familiar expedient of offsetting the chamber.

Two questions in connection with offsetting are: How small should be the clearance between the piston and the flat portion of the head at top center? and What should be the horizontal extent of the offset? The thinness of the clearance space is more important than the extent of the space, provided sufficient gas is included in the highly cooled pocket to prevent detonation from occurring while the flame is still in the relatively hotter gas in the main chamber.

The effect of clearance space in the offset chamber may be likened to cooling hot liquid in a saucer, which may be poor etiquette but is sound engineering. Here also the temperature is determined by the ratio of sur-

face to weight, which is inversely proportional to the depth of liquid. However, every unit of volume of the liquid is cooled to the same temperature. The only advantage of a larger saucer is that it does not have to be filled so often. In the main combustion-chamber we have only to make sure that the flame, before the end of its travel, does not run into any gas that is hotter than the gas in the cylinder clearance-space, which would nullify the benefit of the clearance space. This is easily proved by firing from the piston end of the main chamber. In that case, the last gas to burn is at the valve end of the chamber; and detonation will be governed by the temperature of the gas in that neighborhood, which is equivalent to no governing at all. It is essential to fire no nearer to the piston end than the center of the main combustion-chamber.

The relative importance of the depth of the clearance space and its horizontal extent has been determined by a previously reported series of tests[6] on a single-cylinder engine fitted with heads in which these two factors were varied independently. The heads in one group were identical in all respects except for the height of clearance, which was varied from 1/32 in. to ¼ in. by steps of 1/32 in. Detonation intensity was measured independently by means of a special indicator operating on the bouncing-pin principle and by retarding the spark to eliminate knock. Both methods agree in showing that detonation increases progressively as the clearance is increased, with the exception of the step from 1/16 in. to 3/32 in., where no difference was detected. These tests indicated, as shown in Fig. 6, that clearances up to 3/32 in. give practically the minimum detonation.

Fig. 7 shows the result of varying the horizontal extent of the clearance space for a given depth of clearance from zero to 40 per cent of the piston area. The greatest difference is seen to result from the initial step from zero to 5 per cent piston coverage. From 5 per cent to 10 per cent the benefit is small, and still smaller from 10 per cent to 20 per cent. As the piston coverage is increased above 20 per cent, a slight increase in detonation is noted. This bears out the rational conclusion that the intensity of cooling rather than the amount of gas cooled is the important factor. It would not be safe to generalize from this that 20 per cent piston coverage will always give the optimum result, since this will unquestionably vary with other details, but it can be concluded that detonation is relatively insensitive to change in horizontal extent of clearance space within wide limits. This element of the design can, therefore, be determined by other considerations without regard to detonation.

Coefficient of Heat Transfer and Explosion Time

The most sensitive variable in heat transfer between a fluid and a contacting surface is the resistance to heat-flow offered by the fluid film adjacent to the surface. This resistance for a given fluid is determined by the nature of the fluid flow with respect to the surface, not only as to velocity but also as to direction. The curves of Fig. 8, from experimental data of W. H. Carrier and F. L. Busey, are given merely to illustrate the tremendous influence of velocity and the advantage of flow at right angles to a surface over parallel flow. It will be seen that, in the range of velocity up to 40 ft.

[6] See *Automotive Industries*, Nov. 10, 1928, p. 663.

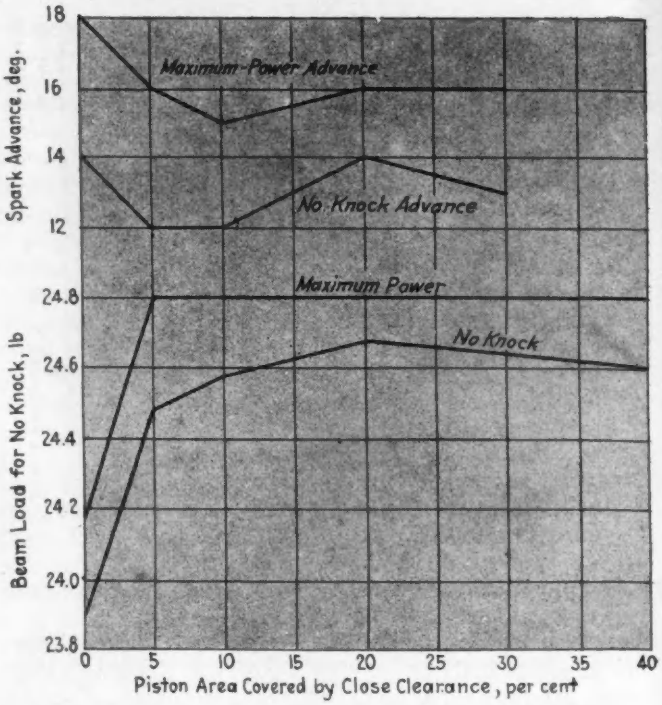


FIG. 7—VARYING THE AREA OF THE CLOSE CLEARANCE

Compression Ratio, 5.38-1 for Zero Area and 4.80-1 for Offset Heads; Spark-Plug at the Center of the Volume; Tests Made at 1000 R.P.M., Under Full Load

per sec., transverse flow in this particular case gave about the same coefficient of heat transfer at one-third the velocity required for parallel flow.

Because of the rapidity of combustion, the displacement of unburned gas ahead of the flame occurs in so short a time that it sets up a considerable velocity of flow of the unburned gas. Although the amount of displacement of a gas particle before burning is smaller the more remote it is from the firing point, a relatively small section-area will increase the movement, as shown at *F* and *G* in Fig. 3. The thin clearance-space in the offset head, therefore, has the additional advantage that the induced velocity of the unburned gas in this space becomes considerable in spite of its remoteness from the firing point. For an average offset head with an explosion time of 0.003 sec., which is not uncommon at high speed, the mean velocity in the clearance space will be of the order of 30 ft. per sec., the maximum velocity being considerably greater. A further advantage is that the velocity of flow is more effective for heat transfer in a thin passage than in a deep one, because there is less velocity-gradient across the passage and the velocity at the surface is nearer the maximum value.

While the clearance space provides the most effective means of cooling the gas that is last to burn, the temperature of the gas entering the clearance space has an important bearing on the resultant temperature. Only 4 or 5 per cent of the total charge may be contained in the clearance space at top center on compression; but additional charge is compressed into it as combustion proceeds, because of both the increasing pressure in the main chamber and the increasing volume of the clearance space due to piston movement. Fig. 9 shows in percentage the variation in the amount of the charge contained in the clearance space during combustion and

the amount of gas burned, both plotted against time, as calculated from the pressure-time card for a combustion-chamber having 3/32-in. minimum clearance and 50 per cent of the piston area covered by the flat of the head. It will be seen that the weight of gas in the clearance space remains very nearly constant at 5 to 6 per cent for the first half of the burning time and then rapidly increases until a maximum of about 19 per cent has been reached at the end of the burning in the main chamber, when the curves for charge burned and charge in the clearance space intersect. Combustion then proceeds to completion in the clearance space.

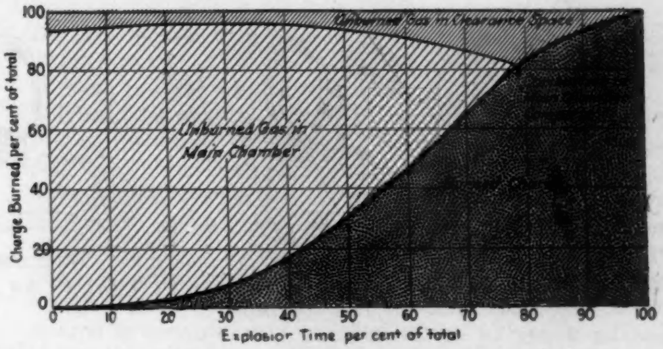


FIG. 9—DISTRIBUTION OF UNBURNED CHARGE DURING COMBUSTION

Movement of the Gas, as Indicated in Fig. 3, Can Be Traced with This Chart, Plotted from a Test of an Engine Having an Offset Combustion-Chamber

Cooling Desirable During Transfer

It is evident from these curves that 75 to 80 per cent of the gas contained in the clearance space when combustion begins therein was originally in the main chamber, and it is important that this gas be cooled as much as possible so as to keep down the resulting temperature of the gas last to burn. For the purpose of illustration, let us return to the analogy of the cup and saucer. We may consider the cup full of hot liquid as analogous to the main chamber, and the saucer as corresponding to the clearance space. The desired result is to obtain the minimum temperature of the liquid in the saucer.

Obviously, it will help if, in addition to the effect of the saucer, we provide a high rate of cooling as the liquid is poured from the cup into the saucer. Suppose we use a strip of relatively cool metal for this purpose. If the strip is held in the direction of flow, as shown at the left in Fig. 10, a certain amount of cooling will be obtained; but, if the strip is held at right angles to the direction of flow so that the liquid impacts upon it before it enters the saucer, the cooling effect will be greatly intensified. This was also shown in Fig. 8. The shape of the impact surface is important, as it affects the direction of flow imposed upon the fluid. If the surface is concave with respect to the flow, as at the right in Fig. 10, the fluid will tend to reverse its original direction, as it will not do with a flat or convex surface.

[7] See *Automotive Industries*, Nov. 3, 1928, p. 622.

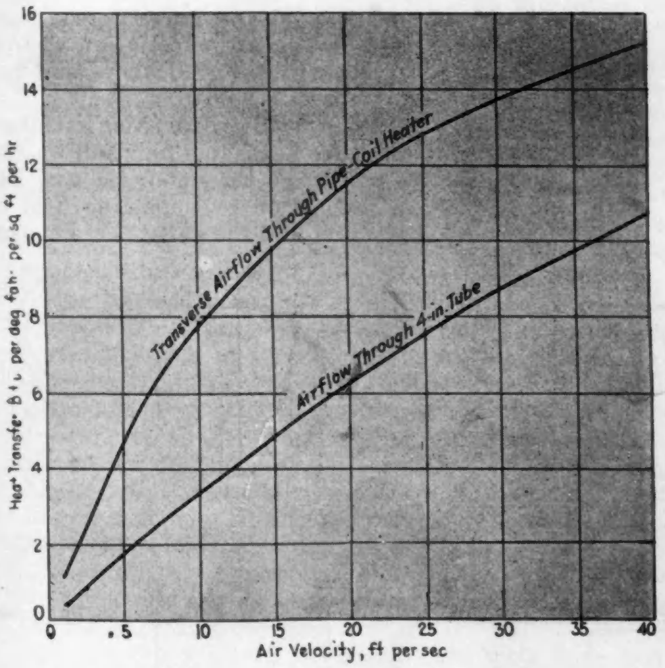


FIG. 8—HEAT TRANSFER AS AFFECTED BY VELOCITY AND NATURE OF AIRFLOW

The conclusions from this analogy can be applied directly to the design of the wall of the combustion-chamber adjacent to the clearance space. The chamber of steamlined longitudinal section, shown at the left in Fig. 11, is far inferior to the square section shown at the right in the same figure, because the flow of the gas into the clearance space is tangential to the surface in the first case, while in the second case an impact surface is provided to cool the gas flowing from the main chamber into the clearance space. As brought out in the analogy, this surface should be plane or convex, rather than concave, to avoid disorganizing the flow of cooled gas into the clearance space.

Turbulence in connection with combustion-chamber design has been so thoroughly sold to the engineering fraternity that it has become a byword, but no clean-cut experimental evidence of its effect on detonation has been brought to light by any of its proponents. There are two aspects to the question of turbulence in this connection; first, How much does turbulence influence detonation? and, second, How much can the combustion-chamber influence turbulence? To answer the first question, I made a bomb investigation which has been reported previously[7].

Effect of Turbulence on Detonation

The conclusions from these experiments were that, although the inherent tendency of turbulence is to reduce detonation, this is opposed by the tendency of reduced explosion-time to increase detonation by lowering the total heat-loss and, consequently, to raise the maximum pressure. The initial effect of turbulence on the explosion time is so great that it overshadows the beneficial effect of the turbulence, and the resultant effect is an increase in detonation intensity. With greater turbulence, the rate of change in explosion time is so much smaller that the tendency of turbulence to reduce detonation asserts itself and produces a net reduction in detonation.

The beneficial effect of turbulence is also apparent in the engine in the characteristic variation in detonation with speed, as reported in the same article[7]. In the representative high-speed engine, in which compression

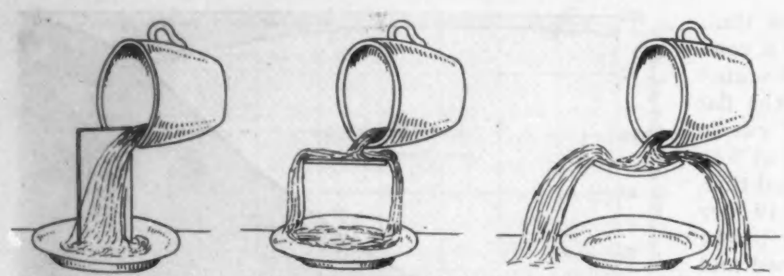


FIG. 10—BAFFLING EFFECT ANALOGOUS TO THAT IN AN OFFSET CYLINDER

pressure and indicated torque peak at speeds of 2000 to 2400 r.p.m., detonation is not found to follow the indicated load, as might be expected. Instead, detonation usually reaches the maximum at 800 to 1200 r.p.m. and tends to remain practically constant until the indicated torque reaches its maximum, after which detonation begins to fall off rapidly. This lack of response of detonation intensity to the considerable increase in compression with increasing speed is explainable only on the basis of the beneficial effect of the rapidly increasing turbulence.

The explanation of the effect of turbulence on detonation lies in its beneficial effect upon the coefficient of heat transfer. The influence of fluid velocity with respect to a cooling surface is really a matter of turbulence in breaking up the heat-insulating fluid-film on the surface and increasing the heat conductivity from particle to particle of the fluid. Thus, turbulence directly increases the heat transfer from the unburned gas to the walls, just as it promotes flame propagation by increasing the rate of heat conduction and convection from layer to layer of the combustible mixture. In addition, turbulence has an indirect influence on the rate of heat transfer from the unburned gas by virtue of its effect on the rapidity of burning. As has been shown, the velocity of flow of the unburned gas ahead of the flame front is largely determined by the flame velocity or burning rate. Turbulence, by increasing the burning rate, produces greater velocities of flow of the unburned gas, with consequent benefit to the rate of heat transfer. This cumulative effect of turbulence on heat transfer thus overcomes the tendency of the accompanying reduction in explosion time to decrease the total heat-loss from the unburned gas, except at such low degrees of turbulence that the effect on explosion time overshadows everything else. There is then no doubt that increased turbulence, if sufficient, does tend to reduce detonation.

This brings us to the second question; namely, Is turbulence affected by combustion-chamber form sufficiently to influence detonation tendency? Since the primary source of turbulence is the high intake-velocity, the production or boosting of turbulence during the compression stroke as the gas is forced into the chamber can be at best only a contributory factor in the effective residual turbulence. Considering that the relatively tremendous effect of engine speed on turbulence produces no outstanding reaction on detonation, it is not reasonable to expect that the smaller possible effect of the chamber form, within ordinary limits of design, can produce any appreciable effect on detonation through turbulence.

It was originally claimed for the offset head by Ricardo, its greatest proponent, that its merit lay in the high turbulence induced by the restricted communicating area between the cylinder and the combustion-chamber. Although Ricardo has since gone to the other extreme in discounting the antiknock effect of turbulence, his original theory has persisted. It is likely to be harder to unsell this idea than it was to sell it in the first place, because it has become a part of the popular credo. However, the tests recorded in Fig. 7 give no evidence that detonation responds to increased turbulence resulting from a decrease in communicating area; they seem to prove that the virtue of the offset head lies entirely in the provision of a high cooling-effect on the last gas to burn.

Temperature Differential

One other basic factor in heat transfer in connection with antiknock combustion-chamber design is the temperature differential available to produce heat-flow. The range of unburned gas temperature during combustion is of the order of 600 to 1000 deg. fahr. With ordinary water temperatures of say 150 to 180 deg., a temperature differential of 450 to 850 deg. is available during combustion. In addition to the resistance of the gas film, already discussed, the heat-flow is opposed by the heat-insulating carbon-deposit on the surface and the resistance of the metal and of the water film on the jacket side of the walls. The well-known effect of carbon deposit on detonation proves its importance in limiting heat transfer. Although the resistance of the metal is relatively small, so that wall thickness is a minor factor, aluminum heads help to reduce detonation. The resistance of the water film, which is analagous to but less than that of the gas film, is extremely important. As in the case of the gas film, the resistance is most sensitive to the velocity of water-flow. It is therefore vital to the antiknock effect that the water circulation be rapid and unrestricted, especially on those surfaces which are effective in cooling the last gas to burn, such as the wall above and adjacent to the clearance space.

The unjacketed surfaces in the combustion-chamber, such as the piston and valve heads, not only fail to contribute any effective cooling to the unburned gas, but may tend to increase detonation by imparting heat to the gas during compression and the early part of com-

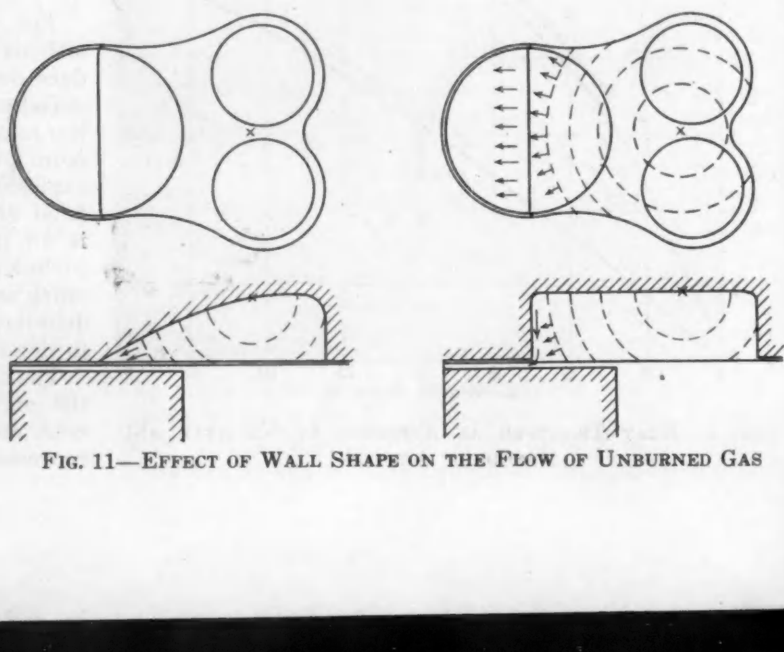


FIG. 11—EFFECT OF WALL SHAPE ON THE FLOW OF UNBURNED GAS

bustion. The piston-head temperature is especially important, because it contacts intimately with the last gas to burn in the clearance space. For this reason, the aluminum piston permits the use of higher compression than the iron piston, although this advantage is not as a rule fully realized because of the practice of making the piston-head as thin as possible for the sake of weight reduction. The lower temperature made possible by judicious addition of metal to the piston-head is well worth the small increase in weight involved.

The exhaust-valve head normally is the hottest surface in the chamber, and as such can be a detrimental factor in detonation. The most effective means of avoiding this is to prevent the unburned gas that contacts with it from being included in the last gas to burn or from influencing the temperature of this gas in any way. Locating the spark-plug in the vicinity of the exhaust valve makes the surrouding gas the first to burn, so that the exhaust valve can do no damage. Firing from the center of the main chamber of an offset head prevents the unburned gas contacting with the exhaust valve from mixing with the gas which is last to burn; but, with firing from over the inlet valve, some of the unburned gas that is swept over the hot exhaust-valve may contribute to the temperature of the last gas to burn. In general, it is undesirable to fire at a point so remote from the exhaust valve that the valve is situated between the spark-plug and the point of maximum flame-travel.

Spark-Plug Location

While the exhaust valve may thus be a contributory factor in detonation, especially if it is not properly considered in locating the spark-plug, it certainly is not the limiting factor that W. A. Whatmough maintains it to be in his extensive writings in the *Automobile Engineer*.

In general, detonation in the offset-type head is not very sensitive to spark-plug location so long as the firing point is no nearer the piston than the center of the main chamber. Results of previously reported[8] tests with various firing positions are shown in Fig. 12. It will be seen that the maximum torque is increased slightly as the spark-plug approaches the center of volume, but the loss in load with spark retarded enough to give borderline knock, as indicated by an *X* on each curve, is closely the same with the exception of position *B*, over the inlet valve, which gave not only the lowest output but a somewhat greater loss in torque for borderline knock.

The application of heat-transfer fundamentals to the problem of intensifying the cooling effect of the chamber walls on the unburned gas can make possible a considerable gain in permissible compression-ratio without detonation and without sacrificing any of the possible gain in efficiency. Figs. 13 and 14 show comparable test-curves for two combustion-chambers on the same engine under identical conditions. Head *A* was a typical offset type of domed contour, fired from about the center of volume, and represents the best conventional L-head design. The compression ratio was 5.4-1. Head *B* is a special design embodying the principles outlined in this paper, giving 5.8-1 compression-ratio. The engine has 3¼ x 4½-in. cylinders. The tests were made with the water outlet-temperature at 180 deg. fahr., and the locked road-setting of the carbureter was used in both cases. The fuel used was a commercial gasoline of none too good antiknock quality.

It will be observed that, in spite of the difference in the compression ratio, which was reflected in a 5.5-per cent gain in both maximum torque and maximum horsepower, borderline detonation in head *B* occurred in no case at less than maximum-power spark-advance; while considerable spark-retardation was required for head *A* with consequent loss in torque at borderline knock. It is also of interest to note that head *B* permitted a considerably greater range of spark advance at high speeds than head *A*. Whereas, objectionable knock occurred at maximum-power advance at most speeds with head *A*, it was necessary to advance the spark to the point of 1-lb. loss to bring in objectionable knock with head *B*.

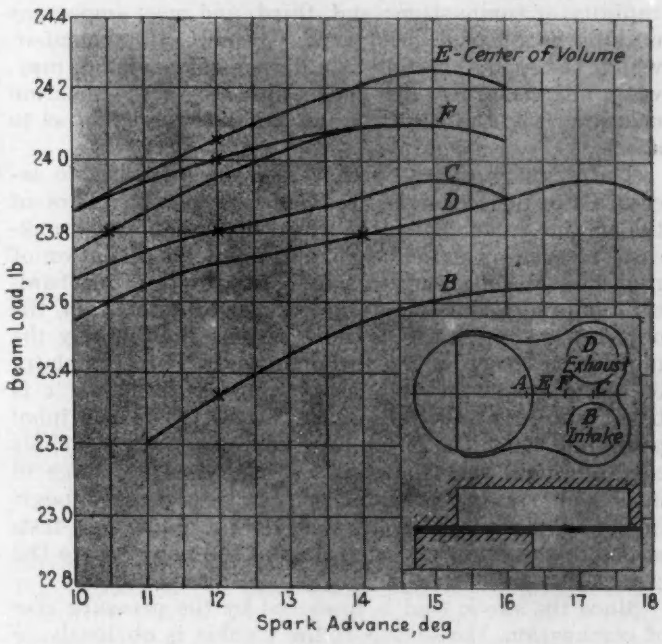


FIG. 12—EFFECT OF SPARK-PLUG LOCATION

From Tests Under Full Load at 1000 R.P.M. on a Single-Cylinder 3½ x 4-In. Engine Having a Compression Ratio of 4.84-1. Borderline Knock Occurs at *X*

The performance of this engine with head *B* at 5.8-1 compression-ratio shows an unusually high level of specific output and efficiency. The maximum corrected horsepower of 119 at 3600 r.p.m. represents an output of 0.4 hp. per cu. in., and the maximum torque of 210 ft-lb. at 2400 r.p.m. represents a brake m.e.p. of 106.5 lb. per sq. in. The specific fuel-consumption reached a minimum of 0.55 lb. per b.hp-hr. at 2800 r.p.m., corresponding to an indicated thermal efficiency of 30.5 per cent. High combustion-efficiency was further indicated by the complete elimination of high-speed miss, which was present in head *A* to a considerable degree at 3600 r.p.m.; also by perfect regularity of operation in idling. Not only was this engine perfectly free from objectionable detonation at 5.8-1 compression-ratio with ordinary gasoline, but the characteristic harshness noted with the original head *A* was conspicuously absent, in spite of the higher compression.

This discussion has dealt primarily with the L-head type of combustion-chamber, but there is no reason why

[8] See *Automotive Industries*, Nov. 10, 1928, p. 664.

the same fundamental principles should not be equally applicable in the case of the overhead-valve engine. While it is true that the limitations to chamber design are inherently greater in this type, these fundamentals have already been successfully applied in one recently introduced overhead-valve engine.

Shock Tendency

The rapidity of pressure development during combustion subjects the engine structure to a shock load which may be considerably in excess of the apparent static load.

High compression tends to aggravate the shock load, for several reasons: First, the pressures are greater, so that the basic load is increased; second, the higher pressures and temperatures of compression increase the rapidity of combustion; and, third, and most important of all, the offset L-head type of combustion-chamber, which has made possible this higher compression, may, when haphazardly designed, produce a combustion characteristic that is the worst possible condition as to shock.

The primary effect of excessive shock-load is to increase the deflection of the load-carrying members of the engine, principally the crankshaft and the crankcase, to such an extent that an unpleasant sensation of roughness results and, in some cases, distinct mechanical bump is produced. As in the case of detonation, the objection to roughness is more serious than merely the unpleasant reaction on the operator. This complaint on the part of the engine is an indication that it is being subjected to destructive forces. The continual pounding which the shock load imposes on the bearings certainly does them no good. I have seen a change in head alone make the difference between cracked bearings and perfect ones after a 100-hr. endurance-test, although the compression ratio and the power were the same.

Since the shock load is produced by the pressure rise of combustion, the source of the trouble is obviously to be found in the characteristic of that pressure rise with respect to time. It is only natural to jump to the conclusion that the maximum rate of pressure rise is the determining factor in shock. However, this is really too superficial to be true, as we found out when we tried to design combustion-chambers around the maximum rate of pressure rise. What happened was that chambers that should have given velvety smoothness, according to this theory, gave a result that was more like sandpaper. After that a new theory had to be found. The next attempt was much closer to the truth. This time we chose the acceleration in the rate of pressure rise as the deciding factor and found that keeping down this acceleration really produced smooth operation.

But guesswork, even when attended by good luck, is not a reliable means of progress, so it was necessary to construct a fundamental picture of the problem in order to determine the true relation of the various factors to the result. Since the measure of shock load is the deflection it produces, let us analyze the pressure-time characteristic for its direct effect on deflection of the resisting structure.

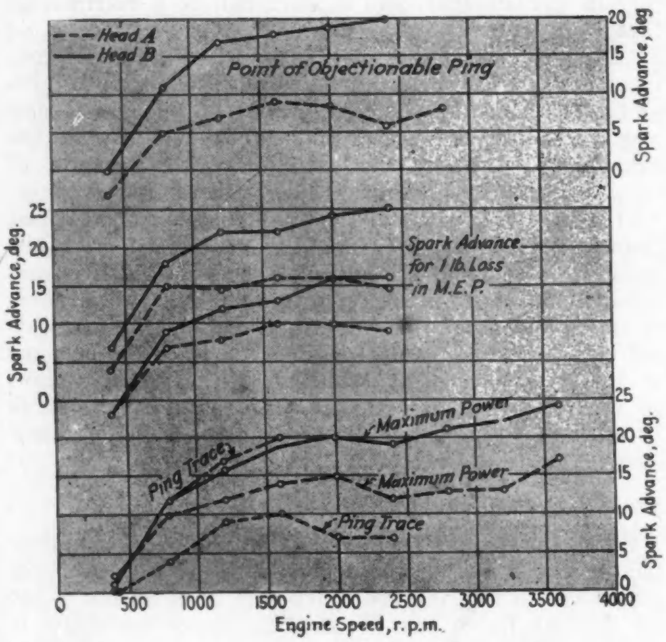


Fig. 14—Spark-Advance Curves Showing Improved Anti-knock Effect with Modified Cylinder-Head

Pressure-Time Characteristic Analyzed

At any instant during the combustion the deflecting structure resists the impressed force with a restoring force which is proportional to its deflection at that instant, if the action is elastic. Also, since the impressed force is constantly changing, the deflecting structure has a definite velocity. If the rate of increase in the impressed force is built up gradually, so that the rate of deflection can follow it, the restoring force will always exactly balance the impressed force and the maximum rate of pressure rise will in itself determine the maximum rate of deflection and, consequently, the dynamic load. However, if the acceleration in the rate of increase of the impressed force is appreciable, a force differential must be provided to accelerate the deflecting mass. This required force-differential can come only from an unbalance between the impressed and the restoring forces. As a result, the greater the acceleration in the increase of impressed force, the greater is the instantaneous lag of the deflecting rate

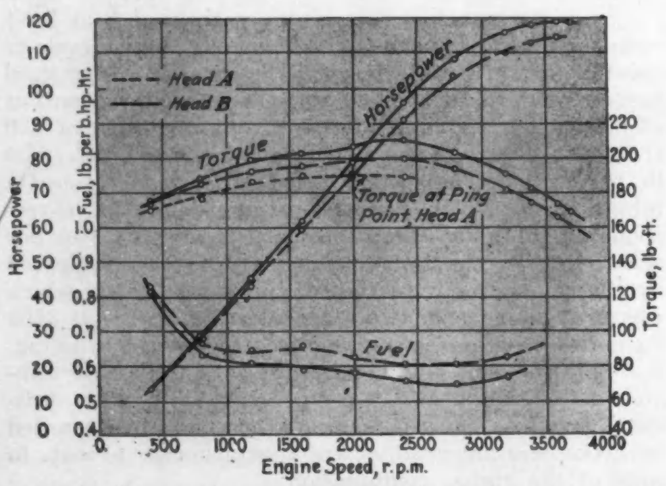


Fig. 13—Power Curves Showing Gain Available from Higher Compression-Ratio

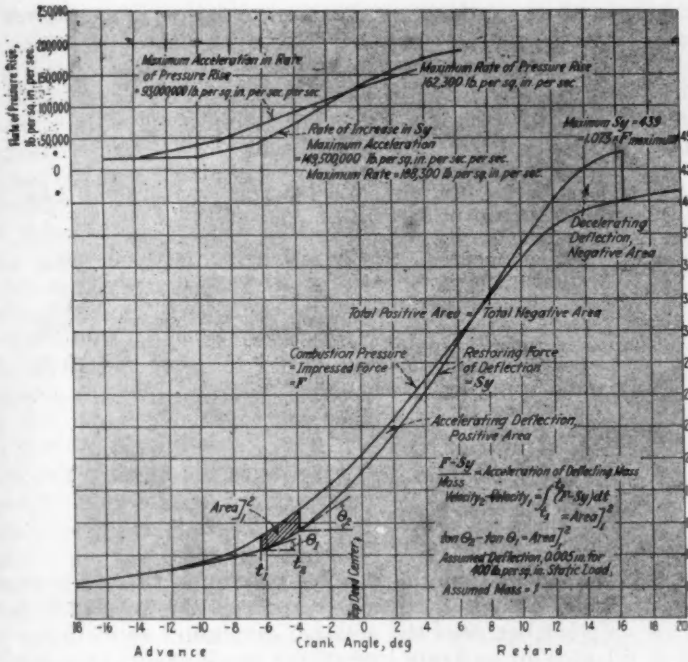


Fig. 15—Smooth Characteristic Charted

Graphical Analysis of Pressure-Time Curve for Explosion Impact at 1600 R.P.M., with a 16-Deg. Spark-Advance and 5.25-1 Compression-Ratio

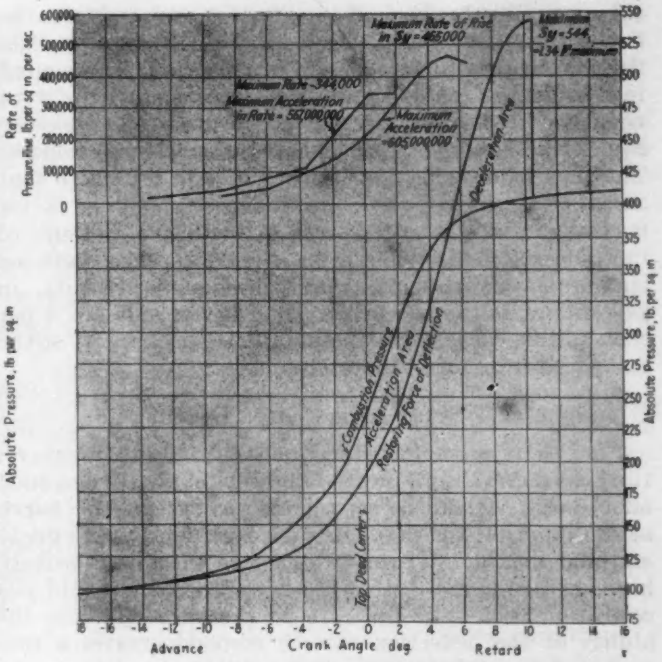


Fig. 16—Rough Characteristic Charted

Analysis Similar to That of Fig. 15, for an Engine Having a 5-1 Compression-Ratio, with Speed and Spark Advance the Same as in Fig. 15

behind the rate of force increase. This lag lasts as long as the acceleration continues undiminished. When the acceleration falls off, however, the force differential which has been created between the impressed and restoring forces becomes effective in accelerating the deflecting mass, with the result that a velocity of deflection is built up in excess of that corresponding to the maximum rate of increase in impressed force.

From this analysis it is evident that no single feature of the pressure-time characteristic can be selected which will give a true quantitative gage of the shock load. This can be obtained only by an integration involving the entire characteristic.

In Fig. 15 is shown a graphical method of making this determination. The pressure-time characteristic in this case represents almost an ideal anti-shock condition, the rate of pressure rise increasing almost uniformly up to the maximum rate, which is seen to be relatively low. It is satisfactory for comparative purposes to select an arbitrary load-deflection characteristic and deflecting mass for a given engine. In this case it was assumed that a static load corresponding to a pressure of 400 lb. per sq. in. produces a deflection of 0.005 in., and that the deflecting mass is unity. These assumptions are probably on the low side. Since the time interval represented by 1 deg. of crank-angle is known from the speed, in this case 1600 r.p.m., the velocity of deflection corresponding to a given rate of load increase is readily obtained and the restoring force may be used to represent the deflection to which it is proportional.

Basis of the Graphical Method

The basis for this diagram lies simply in the fundamental equation that force equals mass times acceleration. Thus, if, in going from t_1 to t_2, in Fig. 15, the deflection velocity, as represented by the tangent to the curve of restoring force, increases from tan Θ_1 to tan Θ_2, then this velocity increase must be equal to an integration of acceleration (a) with respect to time (t), during the same time interval, or

$$\tan\Theta_2 - \tan\Theta_1 = \int_{t_1}^{t_2} a\,dt \qquad (1)$$

Since the acceleration is proportional to the force acting, which is the differential between impressed and restoring forces, the area between the curves of these forces plotted against time, between the limits t_1 and t_2, is proportional to the increase in deflection velocity, or

$$\tan\Theta_2 - \tan\Theta_1 = \int_{t_1}^{t_2} \frac{F}{M}\,dt \qquad (2)$$

in which F is the impressed force from the pressure of combustion and M is the mass of the accelerated parts.

Since the acceleration in rate of pressure rise during the compression stroke is of a low order, the curves of impressed and restoring forces may be taken as being coincidental at ignition. From there, using the relationship expressed in equation (2), the curve of restoring force can be built up step by step so that the increase in slope of the curve between any two limits of time is equal to the area between the two curves, between the same limits, reduced to equivalent terms. It will be seen that the two curves are practically parallel as long as the maximum acceleration is maintained at a uniform value. When the acceleration begins to fall off, the rate of deflection begins to overtake the rate of force increase under the influence of the now excessive force-differential, until the curve of restoring force crosses that of impressed force, at a rate of increase necessarily greater than the maximum rate of pressure rise.

As soon as the restoring force exceeds the impressed force, deceleration of the deflecting mass begins, the

same equality between change in velocity and area between the curves being maintained until the rate of deflection returns to zero at a restoring force corresponding to maximum deflection. At this point, the total negative area, representing the decrease in velocity, equals the total positive area, or increase in velocity. The maximum deflection is what we are trying to find, and its excess over the deflection corresponding to the maximum static load is a true quantitative measure of the shock load. Therefore, the difference between maximum restoring force and maximum pressure, in percentage, is the shock factor. The low value of 7 per cent, in this case, shows the high anti-shock merit of the particular pressure-time characteristic.

A Study of a Poorer Design

Fig. 16 is a similar diagram analyzing a pressure-time characteristic typical of the rough, poorly-designed offset-head. It will be seen, from the rate-of-rise curve at the top, that the maximum acceleration is very great and the maximum rate of pressure rise is relatively high, as compared with Fig. 15. When the rapid acceleration occurs in the rate of pressure rise, the inability of the deflection rate to respond creates a tremedous force-differential. When the acceleration period is over and the maximum rate of pressure rise is attained, the deflection rate begins to accelerate rapidly and in this case reaches a maximum value which represents a considerably greater excess over the maximum rate of pressure rise than obtained in the previous case. Consequently, the restoring force must reach a much greater differential over the impressed force before it can bring the deflecting mass to rest.

The resulting maximum deflection corresponds to a static load of 543 lb. per sq. in., or an increase of 32.5

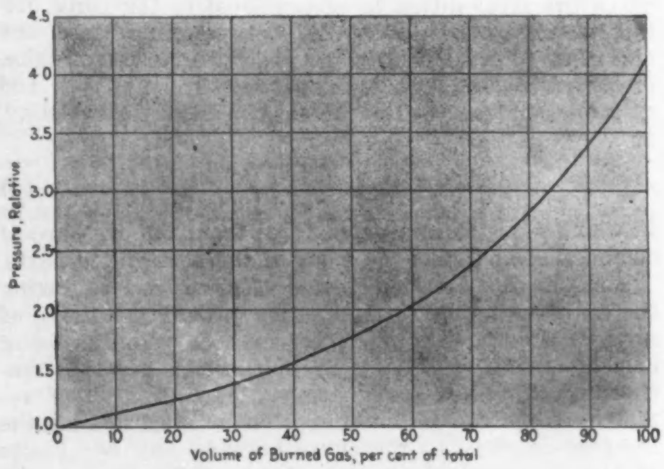


FIG. 17—FUNDAMENTAL RELATIONSHIP BETWEEN PRESSURE AND BURNED-GAS VOLUME DURING COMBUSTION

per cent over the effective maximum pressure. The shock factor is therefore 4½ times as great as with the 7-per cent increase shown in Fig. 15.

From this analysis we can draw certain general conclusions that will serve as a basis for qualitative interpretation of the pressure-time characteristic as to shock effect. The various quantities for the two cases shown in Figs. 15 and 16 are arranged for comparison in Table 1.

TABLE 1—QUANTITATIVE COMPARISON OF SMOOTH AND ROUGH ENGINE

	Smooth, Fig. 15	Rough, Fig. 16	Relative
Maximum Rate of Rise			
Pressure, lb. per sq. in. per sec.	162,300	344,000	2.18
Restoring Force, lb. per sq. in. per sec.	188,370	465,000	2.47
Maximum Acceleration in Rise			
Pressure, lb. per sq. in. per sec. per sec.	93,000,000	567,000,000	6.1
Restoring Force, lb. per sq. in. per sec. per sec.	149,000,000	605,000,000	4.05
Relative kinetic energy of Deflecting Mass, $(2.47)^2$			6.10
Maximum Restoring Force, lb. per sq. in.	439	543.7	
Maximum Pressure, lb. per sq. in.	410	410	
Shock factor,[9] per cent	7.07	32.6	4.6

[9] $\frac{\text{Maximum Restoring Force—Maximum Pressure}}{\text{Maximum Pressure}} —1$

It is evident that the relative maximum rate of pressure rise, 2.12, is no guide to the relative shock effect of 4.6; neither does the relative maximum acceleration of 6.1 give an accurate idea of the shock effect, although it is nearer to the truth than the relative maximum rate of pressure rise. Since the shock effect is a composite of both maximum rate of pressure rise and maximum acceleration, it should properly be intermediate between the two. If we average the relative maximum acceleration and relative maximum rate of pressure rise, in this case, we get a figure of 4.1, which is fairly close to the actual relative shock effect. However, no general empirical formula of that kind can be expected to obtain over the wide range of characteristics represented by different combustion-chambers, primarily because the location of the maximum acceleration in the combustion period has an important bearing on the resulting shock effect. It is apparent from the diagrams that the earlier the maximum acceleration takes place and the greater its duration, the greater will be the final deflection.

It can safely be generalized that the smoothest results will be obtained when both the maximum acceleration and the maximum rate of pressure rise are kept as low as possible. In actual application, maximum smoothness consistent with high efficiency results from as nearly as possible uniform acceleration up to the maximum rate of pressure rise, as illustrated in Fig. 15.

Control of Pressure-Time Characteristic

Having determined the kind of characteristic that is desirable for smoothness, how can we go about building this characteristic into the actual combustion-chamber? The answer to this question also is to be found in the fundamental of flame propagation. As brought out previously, both the burned and the unburned gas are compressed during combustion, the burned gas tending to remain at constant temperature and the compression of the unburned gas being almost adiabatic. On this basis, the relation between the burned-gas volume and the pressure can readily be derived, as shown in detail in Appendix 1. This fundamental relationship is shown in curve form in Fig. 17, assuming that the characteristic n for the unburned-gas compression is 1.25 and that the ratio of maximum pressure to initial pressure is 4.13-1, as determined from average practice.

Thus, if we determine by calculation the percentage

of total volume occupied by the burned gas at any flame-front position, this relationship defines the corresponding relative pressure.

In applying this procedure to a combustion-chamber, the first question to be answered is, What is the form of the flame front? The natural tendency of the flame is to spread at a uniform rate in all directions, so that it would thus be spherical in form. While this has been shown to be true in a quiescent mixture, can it be assumed that it is so in the case of a turbulent mixture? Considering all the evidence, it seems reasonable that this natural tendency of the flame should predominate in spite of turbulence. First, the flame velocity in the engine is unquestionably much greater than any possible turbulence velocities induced in the mixture. Furthermore, there is no reason to expect that the turbulence is in the form of a definite directional movement, especially considering the reversal of flow which occurs between the inlet and compression strokes. It is more likely that the particles of the mixture have an oscillatory movement of relatively small amplitude. Therefore, while the flame front may not be perfectly spherical, it is even less likely that the flame movement will tend to be more rapid in one direction than in another. In the absence of direct experimental evidence, the best proof of the validity of the assumption is in the agreement of the theoretical result with practice.

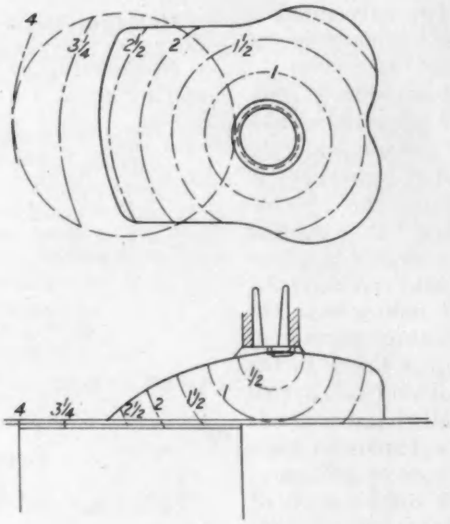


FIG. 18—SKETCH OF COMBUSTION-CHAMBER FOR STUDYING FLAME TRAVEL

If we apply this procedure to a given chamber, as that shown in Fig. 18, calculating the burned-gas volume in percentage of the total at successive flame-front positions, we can plot the volume of unburned gas, in percentage, against the flame travel. Using the fundamental relation of burned-gas volume and pressure from Fig. 17, the curve of pressure against flame travel can also be plotted, but the correlation of pressure with time still remains to be found.

In the physical chemistry of reactions it is fundamental that reaction velocity, or the weight of reagents burned per unit of contact area in unit time, increases directly with the density of the reagents and as some power of their temperature that is greater than unity. Since the temperature, pressure and density of the unburned gas are interrelated according to the characteristic PV^n = a constant, the variation in reaction velocity and, hence, in flame velocity, can be expressed as a function of some power of the pressure, as derived in detail in Appendix 2.

The lower the rate of temperature rise of the unburned gas during combustion, the less will be the acceleration in flame velocity. For this reason, the better the cooling provided by the chamber walls upon the unburned gas, the smaller will be the value of the exponent.

The Progression of Combustion

In determining the relative time during combustion corresponding to each flame-front position, a graphical method is used, as shown in the Fig. 19. Time is obtained by dividing distance by velocity. If the reciprocal of velocity is plotted against distance of flame travel, as in Fig. 19, the area enclosed under the curve will represent time. By dividing the area under the curve at successive flame-front positions by the total area under the curve, the corresponding percentage of total explosion-time is obtained. This is shown in the curve marked Time in Fig. 19.

Now we have only to plot pressure against the corresponding percentage of total time to obtain the resultant pressure-time curve. Fig. 20 shows a calculated curve compared with an actual indicator-card obtained from the same combustion-chamber. It will be seen that, while the two curves do not coincide, they are substantially parallel and exhibit

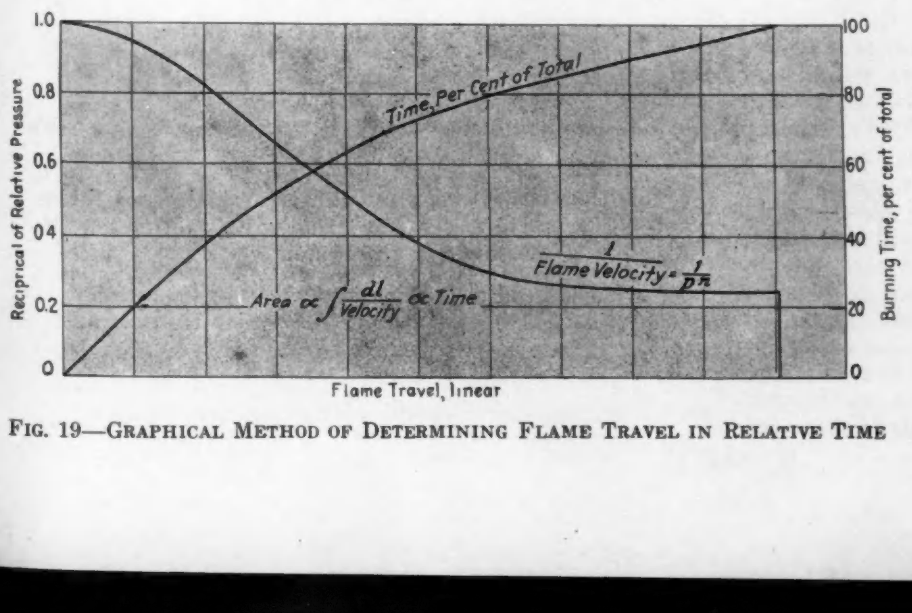


FIG. 19—GRAPHICAL METHOD OF DETERMINING FLAME TRAVEL IN RELATIVE TIME

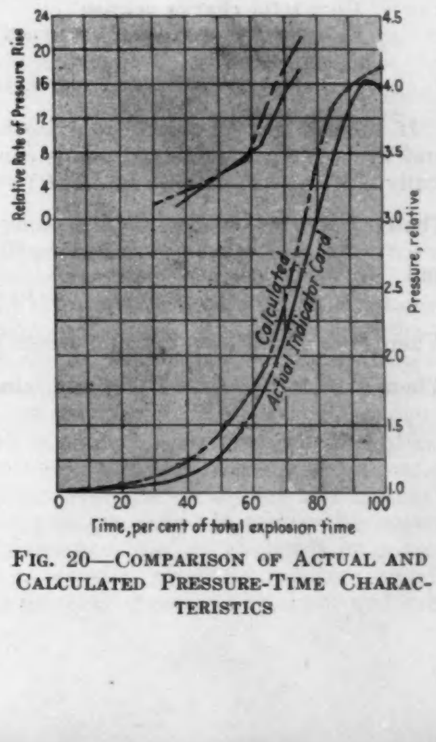


FIG. 20—COMPARISON OF ACTUAL AND CALCULATED PRESSURE-TIME CHARACTERISTICS

the same characteristic. This is clearly evident from the corresponding curves of rate of pressure rise in the same figure, since the values of acceleration in the rate of rise are similar. The somewhat higher maximum rate of pressure rise and maximum pressure for the calculated curves are due to the fact that the piston movement, which tends to lower both of these, was not taken into account in the calculation, since it has little effect on the vital part of the curve. The agreement as to the factors determining the shock tendency is unquestionable.

It is thus possible to predict the pressure-time characteristic for any combustion-chamber with reasonable assurance, provided the constants for the general type are known. In this way, the cut-and-try process required to obtain a smooth characteristic can be confined to paper and the final result assured. It is evident from the diagrams that increasing the length of flame travel in the main chamber of the offset-type head, by making the chamber less compact, will reduce both the acceleration in pressure rise and the maximum rate of pressure rise. However, there are definite limits to the extent to which this non-compactness should be carried with high compression, both because the chamber tends to become too shallow and because the explosion time may be increased enough to cause a loss in efficiency. Reliance must be placed on the proper distribution of the volume with respect to the firing point, if smoothness is to be obtained without sacrifice of efficiency.

APPENDIX 1

Relation Between Burned-Gas Volume and Pressure

In deriving the relationship between the volume and the pressure of the unburned gas, the following symbols are used:

C = a constant
K = a constant
P = absolute pressure
P_m = maximum pressure
P_o = pressure at ignition
q = percentage of charge burned
V_b = specific volume of burned gas on total charge weight
V_t = total charge volume
V_u = specific volume of unburned gas on total charge weight
v = burned-gas volume, percentage of total

If burned gas is compressed isothermally, $PV_b = C$ and $V_b = C/P$; if unburned gas is compressed polytropically, $PW_u^n = K$ and $V_u = (K/P)^{1/n}$.

Then

$$qV_b + (1 - q)\,V_u = V_t$$

and

$$qC/P + (K/P)^{1/n} - q\,(K/P)^{1/n} = V_t \qquad (3)$$

When $P = P_m$, $V_b = V_t$; and when $P = P_o$, $V_u = V_t$. Then, $C = P_mV_t$; $K = P_oV_t^n$ and, since $\frac{qC/P}{C/P_m} = v$, $q = (P/P_m)\,v$.

Substituting in (3)

$$vV_t + (P_o/P)^{1/n}V_t - vP\,P_o^{1/n}/P_mP^{1/n}V_t = V_t$$

$$v\left[1 - \frac{P\,P_o^{1/n}}{P_mP^{1/n}}\right] = 1 - (P_o/P)^{1/n}$$

$$v = \frac{1 - (P_o/P)^{1/n}}{1 - P^{1-1/n}P_o^{1n}/P_m} \qquad (4)$$

APPENDIX 2

Relation Between Flame Velocity and Pressure

In deriving the relationship between flame velocity and pressure, the following symbols are used:

C = a constant for the combustible mixture
D = density
$m = xn/(n-1)$
P = pressure
T = absolute temperature of unburned gas
V = specific volume
W = reaction velocity = weight of gas burned per unit of contact area per unit of time

$PV^n = K$; and $T \propto P^{n/(n-1)}$
$W = CDT^x$
Flame velocity $= W/D = CT^x = FP^m$

APPENDIX 3

Explosion-Shock Diagrams

Following are the symbols used in the computations for the explosion-shock diagrams:

a = acceleration
F = impressed force = pressure, in pounds per square inch
f = resultant force
M = deflecting mass per square inch of piston area
S = force required to produce unit deflection, in pounds per square inch
Sy = restoring force of deflection
V = velocity of deflecting mass
y = deflection

$$dV = a\,dt \qquad a = f/M \qquad f = F - Sy$$

$$dV = \frac{(F - Sy)\,dt}{M}$$

$$\int_{V_1}^{V_2} dV = \int_{t_1}^{t_2} \frac{(F - Sy)\,dt}{M}$$

$$V_2 - V_1 = \int_{t_1}^{t_2} \frac{(F - Sy)\,dt}{M}$$

$\frac{d\,(Sy)}{dt} = S\frac{dy}{dt} = SV = \tan\Theta$ = slope of curve of restoring force

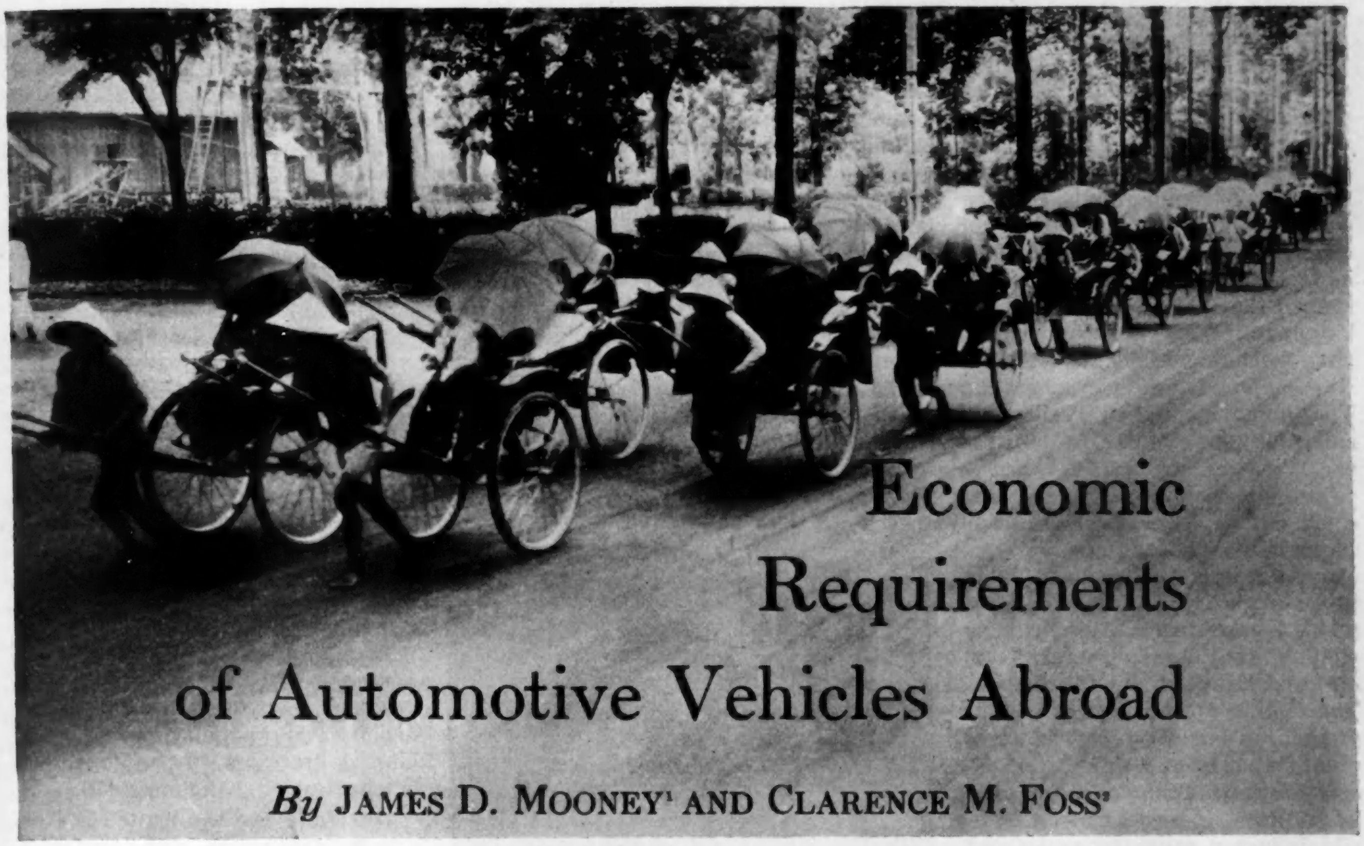
$$V = \frac{\tan\Theta}{S}$$

$$V_2 - V_1 = \frac{\tan\Theta_2 - \tan\Theta_1}{S}$$

Therefore

$$\tan\Theta_2 - \tan\Theta_1 = \frac{S}{M}\int_{t_1}^{t_2} (F - Sy)\,dt \qquad (6)$$

or, the increase in slope of the Sy curve from t_1 to t_2 equals the area between the curves of impressed forces and Sy or restoring forces from t_1 to t_2, times S/M, which is a constant for the system.



Economic Requirements of Automotive Vehicles Abroad

By JAMES D. MOONEY[1] AND CLARENCE M. FOSS[2]

ANNUAL MEETING PAPER — *Illustrated with* PHOTOGRAPHS

AFTER considering from all viewpoints the factors involved in the overseas motor-vehicle market, the authors come to the conclusion that, to satisfy more generally the economic requirements of automotive road-vehicles abroad, developments in three directions are desirable.

First, we should continue to improve present American automobiles, and intensify effort to make them more readily available to the buying public. Special consideration should be given to the open car. This phase is to provide products for income receivers above the level of the large class of small-income receivers.

Second, an entirely new product should be provided for individual transportation, in the form of a car smaller and lighter than the present smallest American automobile and less expensive to own and operate. This would provide transportation for a larger number of income receivers and fulfill the needs of a much greater potential market than exists for the present product.

Third, motor-trucks and motorcoaches should be provided for organized communal transportation. These are needed for low-cost mass movement of passengers and bulk movement of goods, and would open up a still greater potential market.

THE MAJOR consideration in providing automobiles for any market is to develop products that will meet the needs of that market. To develop suitable products, it is necessary to understand what these needs are; and, since it is desired to determine the economic requirements of automotive vehicles abroad, the problem will be to define the overseas market, to analyze and determine its needs, and to establish the requirements of products to fill these needs.

Considering the overseas problem as one of similar character to that of the American problem, it seems logical that the same engineers who arrived at a solution of the American problem should arrive at a solution of the overseas problem. Nowhere in the world can the purchaser obtain such reliable and satisfactory automotive transportation for so little in relation to his purchasing power as he can in the United States.

Those who are intimately identified with the automobile business in this Country have a clear picture of the American market but, unless we are directly engaged in some overseas automobile business and are thoroughly familiar with the economics and history of the overseas countries, we may not see the background or shadows of the overseas picture as clearly as is necessary if we are to develop products required to meet the needs of that market. American customs and habits

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are much the same throughout our entire Country, but in the overseas market every known difference in customs and habits exists. Tariff barriers exist between all nations, interposing trade restrictions, and border difficulties and duties are necessary considerations. A review of the overseas market indicates that there are approximately 300 different countries, 14 languages being spoken commercially in them. Of very great importance is the British Empire, containing about 55 countries; and, while the English language is the commercial language, many different native languages are spoken there. Great technical differences exist between languages. Very few countries in the overseas market have mechanical background or tradition of machinery. Raw materials are even more important in this respect. They must have been available and in use over a considerable period for a people to become skilled in their use.

The question has often been raised why automobiles could not be developed successfully in various overseas countries. The automobile requires highly specialized technique in design and development, plus machinery particularly adapted to its manufacture, and organized skill in its fabrication. The tooling-up process for volume production at low cost involves great expense and particular experience in this type of mechanics. In addition, a successful automobile industry must be supported by allied industries supplying the necessary raw and finished materials, equipment and specialties peculiar to it. Such countries as England, France, Germany and Italy have both raw materials and a background favoring the manufacture of automobiles; and these four countries will supply most of the automobiles manufactured abroad for years to come. It will be some time, to say the least, before automobiles can be manufactured successfully, as distinguished from assembling, in China, India, South Africa, Australia and the various countries of South America.

CLARENCE M. FOSS

The overseas market covers 7½ times as much territory as the American market and contains 12½ times as many inhabitants. The British Empire covers 26 per cent of the area of the overseas market, and contains 27 per cent of the people. It has 3¾ times as many inhabitants as the United States and is 4¼ times as large. The United Kingdom contains an area only 3 per cent of that of the United States, yet it has almost 39 per cent as many inhabitants. The density of population of the United States is 40 per sq. mile; of the United Kingdom, 479.

TABLE 1—COMPARISON OF AREAS AND POPULATIONS OF FOREIGN AND DOMESTIC MARKETS

Country	Area	Population	Density per Sq. Mi.
United States	3,000,000 sq. mi.	118,500,000	40.0
	Times United States	Times United States	
China	1 1/3	3	87.7
India	6/10	2 2/3	176.7
Africa	3 3/4	1 2/10	12.2
South America	2 1/4	6/10	10.4

Australia and the United States are relatively the same in area but the population in the United States is 19 times that of Australia. The number of people in New York City alone is about the same as that in all of Australia.

In comparison with the United States, the area, population and density of population for four great divisions of the overseas market are shown in Table 1.

Distances between main cities in the American market, while fairly great in miles, are comparatively short from the viewpoint of travel time. In the overseas market the distances and time from New York City and from Detroit to principal points are much greater. Some comparisons are indicated in Table 2.

TABLE 2—DISTANCE AND TIME BETWEEN PRINCIPAL AMERICAN AND FOREIGN CITIES

For Passengers		
New York City to	Miles	Days
Montreal, Canada	400	½
Detroit	650	¾
Vancouver, B. C.	3,125	4¾
San Francisco	3,175	5
London	3,800	7
Paris	3,700	7
Berlin	4,400	10
Port Elizabeth, South Africa	11,850	25
Bombay, India	11,750	26
Perth, Australia	13,650	31
Java, via Suez Canal	13,650	35
For Freight		
Detroit via New York City to		
Stockholm, Sweden	5,760	30
Bombay, India	10,070	44
Port Elizabeth, South Africa	8,950	47
Osaka, Japan	12,030	53
Melbourne, Australia	11,550	62

In the overseas market there is every kind of climatic and physical condition known to the world, and in addition the movement of goods is subject to all kinds of restriction. In general, locomotives are not as powerful, trains not as long, and freight-cars do not have the capacity of those in America. Various gages of railroad are used in the same country, making unloading and reloading necessary at points of change. Freight rates in general are high and in some countries prohibitive. In Australia there are three different gages, and a passenger traveling from Brisbane to Perth, about the same distance as New York to San Francisco, uses nine different trains, changing eight times. Transporting freight by railroad in Australia generally is prohibitive both as to

time and cost. Local boat transportation overseas is often necessary and frequently far from ideal. In many instances the boats are small and operate on infrequent schedules. Space is difficult to obtain with regularity and certainty; cases containing cars and parts are roughly handled and often mutilated, and rates, as a rule, are high.

In the overseas market there are wide and narrow roads, ordinary dirt roads and paved boulevards, and camel trails and jungle trails, some of which date back, probably, to the beginning of man. In some of the newer countries, roads and streets are developing along with the automobile. In general, more roads are available throughout the world than there are automobiles to use them, and in this respect roads today are not a limiting factor in the number of automobiles that can be used.

The various automobile taxes and license fees in this Country are sufficiently low and so arranged that they do not limit the usefulness of the automobile by reducing the purchasing power of the individual, or restrict the engineer to any specific type or design of engine or car. In the overseas market there are taxes and license fees of many kinds, some of which, in the form of direct horsepower-taxes, not only limit engine design and type of car but add an over-all cost to the automobile, either reducing the number of or imposing an undue burden on users.

It does not seem logical that taxes of this character can survive. Therefore it is not economically sound to design automotive vehicles specifically to conform to taxes of this nature. The thing that is needed is a product that meets the economic requirements.

One of the important differences between the United States and overseas countries, particularly the older countries throughout Europe and the East, is the existing dwelling and garage arrangement. In some of the newer countries, such as Australia, New Zealand and the various South American countries, the automobile is going hand-in-hand with the building-up of the country and provision is being made for the garaging of automobiles, as in the United States. But generally throughout Europe, where the towns and cities have been in existence for many years, absolutely no provision has been made to use and house automobiles on the same scale as in America. Space is limited, houses are grouped closely together, and in the older sections garages and space for garages do not exist.

JAMES D. MOONEY

With the number of nations and forms of government throughout the overseas market, different ideas, customs and habits, desires and policies have developed, resulting in definite international prejudices and national preferences which are factors in the consideration of providing automobiles for these markets. The English system of measurement has been adopted as standard in the American market. In the overseas market both the English and the metric systems are used. In some countries the English system is standard; in other countries, the metric system; while in still other countries both are used to some extent.

In the American market the American and Canadian currencies are based on the decimal system and represent much the same values, while banking facilities are universal and the methods are fairly uniform. In the overseas market, something like 35 different major kinds of money are used, and banking methods and conditions differ widely.

Overseas there are problems of labor unions, sometimes very active and often radical; of native labor, involving language considerations, traditions and customs; of taxes concerning workmen and employer; and of various laws concerning workmen and working conditions, all very different from those within the United States.

Some of the major differences between the markets under consideration have a direct bearing on the economic requirements of a product for these markets, while others have an indirect bearing and are to be considered in the over-all problem according to their relative importance. A number of these are factors in the increased over-all costs of automobiles when they are moved into the overseas markets.

The economic needs of the overseas market for motorized transportation are, if anything, more pronounced than within our Country; but the purchasing power of the prospective buyer is generally lower, the initial cost and operating cost are both higher, and the type of vehicle being supplied does not fully meet the requirements of low-cost transportation.

Seventy-eight per cent of the estimated number of all the cars in the world are now in use in the United States, and this Country builds 84 per cent of all the cars produced in the world. The next important producing countries are Canada, 3.9 per cent; England, 4.2 per cent; France, 3.8 per cent; Germany, 1.8 per cent; and Italy, 1.0 per cent. All the other producing countries combined account for only 0.6 per cent of the world's total. As regards wholesale value of product, the American automobile ranks first among all industries in the United States.

United States Exports Equal Europe's

The overseas market now absorbs approximately 1,200,000 automobiles per year. About one-half of these are supplied by the United States, the other half being made by European companies. Only 600 cars were imported into the United States in 1928.

American-type automobiles meet the needs of certain markets and influence standards of performance throughout the world. International competition has lowered prices generally and resulted in the develop-

(LEFT) COMMUNAL TRANSPORT IN PERSIA, SHOWING PASSENGER AND FREIGHT LOAD LEAVING TEHERAN FOR THE INTERIOR

(ABOVE) A MIXED LOAD OF PASSENGERS, HOUSEHOLD GOODS AND FARM PRODUCE ON MOVING DAY IN EGYPT

ment of beautiful cars that are economical and of excellent performance. A few years ago the European car set the style; today, the American car establishes the criterion of beauty as well as of performance.

The American passenger-car extends through a range of price classes from low to high, but, irrespective of the price class in which a particular car is located, that car is very largely "standardized" with relation to any other American car in any other price-class.

No Counterpart of European Light-Car

An outstanding example of a type of car that is different from American cars is the European light car. This is made in two sizes: one a very small car like the Austin 7 and the other a medium-size small-car like the Morris 12. An interesting point of difference between European and American cars is the tread, which varies from 38 to 58 in. and seems to have a relation to the wheelbase.

About 15 years ago an attempt was made to produce a type of light car in the United States but it fell short, perhaps from want of a complete analysis of the requirements or because the attempt was premature. But in Europe today the light car is taking a leading position.

The American commercial-car, from the light-delivery vehicle to the heavy motor-truck, also has been developed along standard lines; regardless of price or class, there are common characteristics in construction. European trucks are similar in character to those made in America, but, as regards the number in use, they have not progressed as rapidly as in the United States. The development of standard types of commercial-vehicle body has made much more headway in the last few years in the United States than in overseas countries.

The American motorcoach is younger than either the motor-truck or the passenger-car and is being developed along lines of standard practice. The use of motorcoaches throughout the world is far below the extent of this form of transportation in our own Country. Meeting the requirements of mass passenger-transportation in the overseas market is a definite problem.

In some of the European plants the output of automobiles is approaching a volume comparable with that in some plants in the United States. Production costs in them have not yet reached the same low level as in the American plants but the European manufacturer is taking every advantage of uptodate machinery, tools and processing, and is making rapid progress in the direction of lower costs. In this connection it is interesting to observe that Citroen in France, Opel in Germany, Fiat in Italy, and Morris and Austin in England —all outstanding manufacturers in Europe—produce most of the European automobiles made and sold overseas. Each of these companies produces a light car, it being manufactured in the greatest volume.

The total number of automobiles in the overseas market has been increasing gradually since 1921, with a greater rate of increase in the earlier years than at present. The American automobile, from 1921 to 1923, had a high rate of increase; from 1923 to 1925 the rate of increase declined; from 1925 to 1927, there was a decrease in volume; but during 1928 the trend changed, with an increase in both volume and rate. At the end of 1928, the curves of registration for the American car and the European car were very close together, with the former slightly above the latter.

The number of passenger-cars registered in overseas countries is about 3½ times the number of trucks. In 1928, in the four principal manufacturing countries, European automobiles were leading American automobiles by more than 50 per cent, while in the other countries outside of the four principal manufacturing countries the position was reversed.

Price-Level Position

Immediately the American car arrives in the overseas market, its retail price advances considerably over its retail price in the United States, and as a result each car steps up into a higher price-class, or at least changes position from a low level to a high level within a price class. As an example of price-level change, we cite the case of the Ford and the Chevrolet, two cars at the bottom level of the low-price class in the United States. When these two cars are moved into the overseas market, their prices are increased an average of

105 and 87 per cent respectively, resulting in an advance in price class. Consider the reaction that such an advance in price of these two cars would have in their position in the American market.

Within the last five years, three low-price American cars have been increased in size, weight and price. The price increases were as follows:

Car	1924	1926	1928	1929	Increase, Per Cent
Ford Roadster	$260[a]			$450	73.0
Ford Touring	290[a]			460	58.0
Ford Commercial Chassis	230[a]			325	12.6
Ford Truck Chassis		$325		540	35.5
Chevrolet Roadster	490			525[b]	7.1
Chevrolet Touring	495			525[b]	6.1
Chevrolet Commercial Chassis			$375	400[b]	6.7
Chevrolet Truck Chassis			495	545[b]	10.2
Whippet Touring			455	475	4.5

[a] Without starter and demountable rims, for which add $85.
[b] Six-cylinder model.

It will be noted that five years ago a purchaser in the United States could obtain a two-passenger car for as little as $260, and a five-passenger car for $290. Today that same make of two-passenger car costs $450, or an increase of 73 per cent, and the same make of five-passenger car costs $460, an increase of 58 per cent. The table shows that all the models listed were lower in price in the years previous to 1929. An increase of 30 per cent in this low-price range makes a difference of one price-class, and an increase of 70 per cent makes a difference of almost two price-classes.

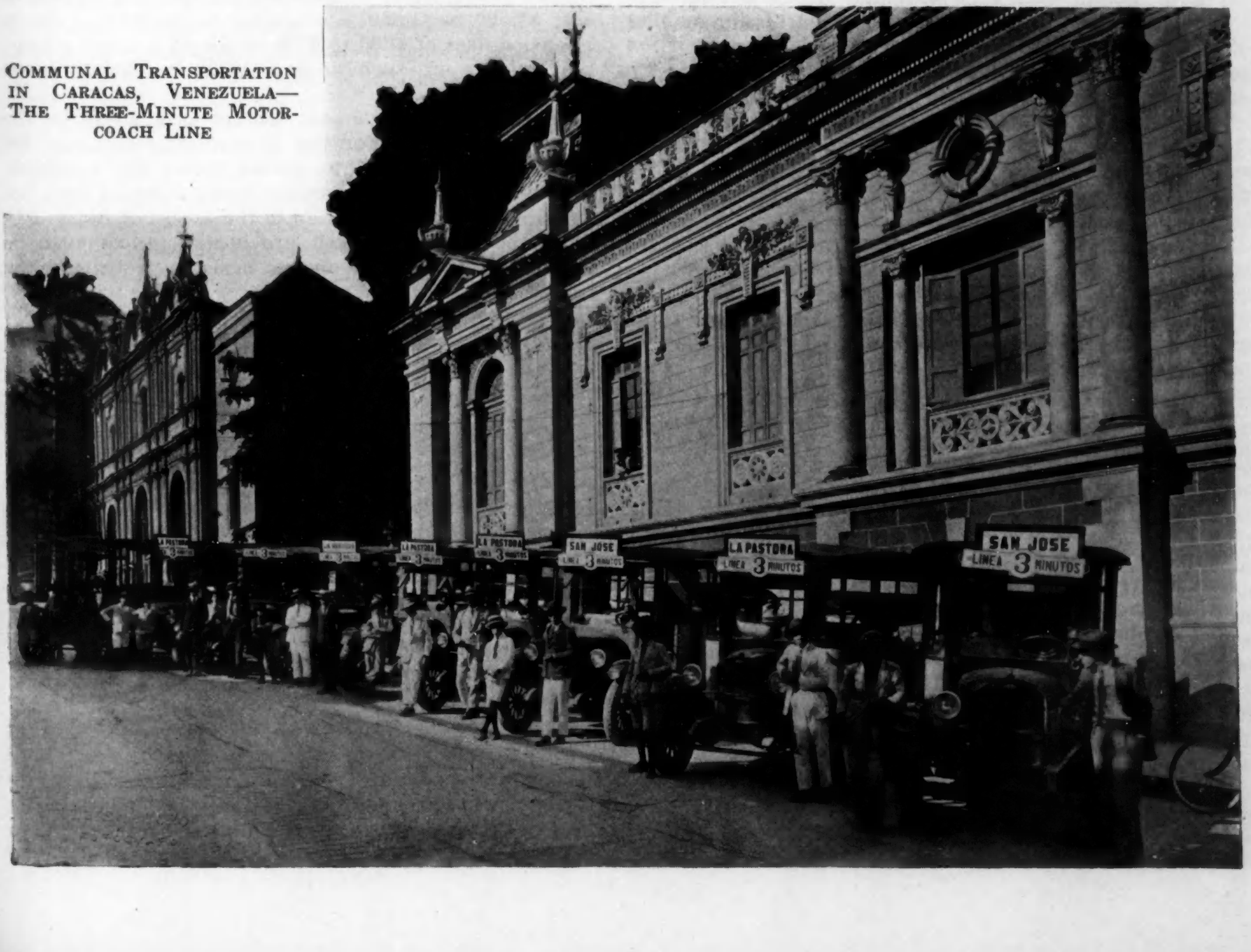
Conditions in the United States have been changing; purchasing power has increased, demands are for larger and better cars, and in consequence, prices have risen. This trend is in exactly the opposite direction to the economic needs of the overseas market. The lowest-price American car in the overseas market today sells for around $800, which is an increase of about 200 per cent over the price of the lowest-price car that could be purchased in the American market several years ago.

Never has there been an American car in the overseas market selling for as low as $260, or even $350. The $260 car in the American market was in a market of high purchasing power. The $800 American car overseas is in a market of only about 66 per cent the purchasing power of the American market, and at the same time is more expensive to operate there than in the United States.

In examining the prices of American cars moved into the different overseas countries, an interesting comparison will be noted between the American car-prices and (*a*) the prices of English, French and Italian cars in the English market, and (*b*) French, German and Italian cars in their own home markets. A number of European cars are in a lower price-level than the low-price American cars in European markets.

Automobile taxes in various forms throughout the overseas market, particularly the direct horsepower and

COMMUNAL TRANSPORTATION IN CARACAS, VENEZUELA—THE THREE-MINUTE MOTOR-COACH LINE



piston-displacement taxes, have a bearing on the over-all cost of cars. As an example of the effect a horsepower tax has on the selling-price, the increase in price of a four-cylinder American car with sedan body in six principal cities of the world in 1928 is shown below. Wealth per capita is also shown as a matter of comparison.

Small-Motorcoach Transportation in a Typical Welsh Countryside

On the basis of the use made of automobiles in the United States, a great many more can be used in overseas countries, provided the right kinds of product are supplied. The entire world needs passenger-cars, trucks and motorcoaches. Automobile manufacturers throughout the world have only begun to supply the need.

National wealth, distribution of wealth, and wealth per capita are, of course, factors in the ability of a country to absorb automobiles. Overseas countries are all lower in national wealth and have less per-capita wealth than has the United States. Dividing the national wealth of the United States among its 118,500,000 inhabitants, the per-capita wealth is estimated to be about \$3,000. Considering this figure for the United States as 100 per cent, the percentage of the United States figure ranges from 90 per cent for Great Britain to 13 per cent for Bolivia. In general, those countries having high per-capita wealth, like New Zealand, Great Britain and Australia, also have a high proportion of automobiles to inhabitants, but throughout the world the proportion is much lower than in the United States.

Place	Retail Price	Tax	Total	Wealth per Capita, Per Cent
Detroit	\$675.00	\$13.20	\$688.20	100
Berlin	1,100.00	96.25	1,197.00	41
London	1,142.00	106.00	1,248.00	90
Port Elizabeth, S. A.	1,287.00	15.00	1,302.00	23
Wellington, N. Z.	1,355.00	9.75	1,364.75	92
Melbourne, Aust.	1,527.00	26.75	1,554.50	95

The ratio of per-capita wealth in the following 13 countries to the per-capita wealth in the United States is estimated to be 66 to 100, approximately \$2,000 to \$3,000.

Argentina	Denmark	Spain
Australia	France	Sweden
Belgium	Great Britain	Switzerland
Brazil	Germany	Uruguay
	New Zealand	

Low-Price-Class Market Potentialities

In the United States, it is calculated that one out of every three persons is an income receiver, while, in the export group, we estimate that one out of every four and one-half persons is an income receiver. Based on the low-price class of \$300 to \$400 in 1928, it is calculated that 50 per cent of the income receivers in the United States, or about 16.7 per cent of the population, are potential car-buyers. In the 13-country group, based on the low-price class of \$800 to \$900 for American cars, it is estimated that about 14½ per cent of the number of income receivers are potential car-buyers. This works out to something like 8,000,000 people. It is estimated that, if the price class were lowered to \$600 to \$700, about 28 per cent of the income receivers would be potential car-buyers.

It has been calculated that an income of \$900 to \$1,000 is required to purchase a car in the low-price class of \$300 to \$400 in the United States, and one of \$2,000 to \$2,100 to purchase a car in the price class of \$800 to \$900 in the 13-country overseas group, where the number of such income receivers is about 603,000. On the other hand, it is estimated that an income of only \$1,500 to \$1,600 is necessary to purchase a car in the price class of \$600 to \$700 in the 13-country group; the number of such income receivers being about 2,207,000.

Considering the overseas market as a whole on the same basis as that for the 13-country group just described, and taking into consideration the necessary factors for the entire market, it is estimated that potentialities can be opened up to the extent of 2¼ to 2½ times the present market, provided a product can be supplied on the same economic basis as prevails in the United States.

Recommended Procedure

To provide products better suited to meet existing needs, it is recommended to:

(1) Continue the work of improving automobiles, and further intensify effort to make the *present type of automobile* more readily available to the buying public

(2) Provide an entirely new product for individual transportation in the form of a *light car*, in a proper price-class; meeting the needs of a much greater potential market

(3) Provide suitable products for *organized communal transportation*, including various types of motor-coach and motor-truck for mass movement of people and bulk movement of commodities

The present type of American automobile is being sent into the overseas market at the rate of more than 600,000 units per year. The product, as it stands, partly fulfills the requirements of this market but, since its use is restricted by known factors, the problem is to overcome these restrictions so far as possible. The

market needs products of this type, but ownership and use should be made as easy as possible.

Development of Open Car Recommended

During the last few years, much more engineering effort has been given to the closed car than to the open car. Costs have been reduced more in proportion for the closed car than for the open car, resulting in open cars costing as much as closed cars in many cases. As previously pointed out, we have not, even in the United States today, an open car in a true low-price level. Much less have we an open car in the low-price level in the overseas market. Inherently, the open car is less expensive than the closed car. It has greater possibilities in lower-cost transportation. Overseas, open cars are entirely acceptable to a portion of the market. Lowering the price level would make them even more acceptable. The requirements are low over-all cost.

New Light-Car Type Proposed

To meet the demand for lowest-cost individual automotive transportation, we recommend an entirely new product in the form of a light car. It should be smaller and lighter than the smallest present American car, and less expensive to own and operate. It is important in the design and development of the light car that consideration be given to the factors of appearance, comfort, price and performance. The ways in which these enter into the problem are as follows:

Appearance.—The car should have correct proportions and the general characteristics of the average first-class automobile of today. It should be small but not ridiculous. It should be good-looking and appealing. The appearance must be all that can be asked for.

Comfort.—The car must be comfortable not only to sit in but to ride in and operate, and easy to take care of and service.

Price.—Dollar value is more important than list-price. High quality should be maintained in both workmanship and material.

Performance.—The car must be efficient and economical to operate and maintain. This means low gasoline and oil-consumption, high tire-mileage, easy inexpensive service, long car-life and high second-hand value. Any part required to make a complete unit should be included, omitting all unnecessary parts. The weight must be reduced to the minimum. Excessive power is not recommended. Above all, the car must be inexpensive to own and to operate.

Wherever we go in the overseas countries, we find the small European car establishing its position, although inadequate for our ideal purposes.

Organized Communal Transportation

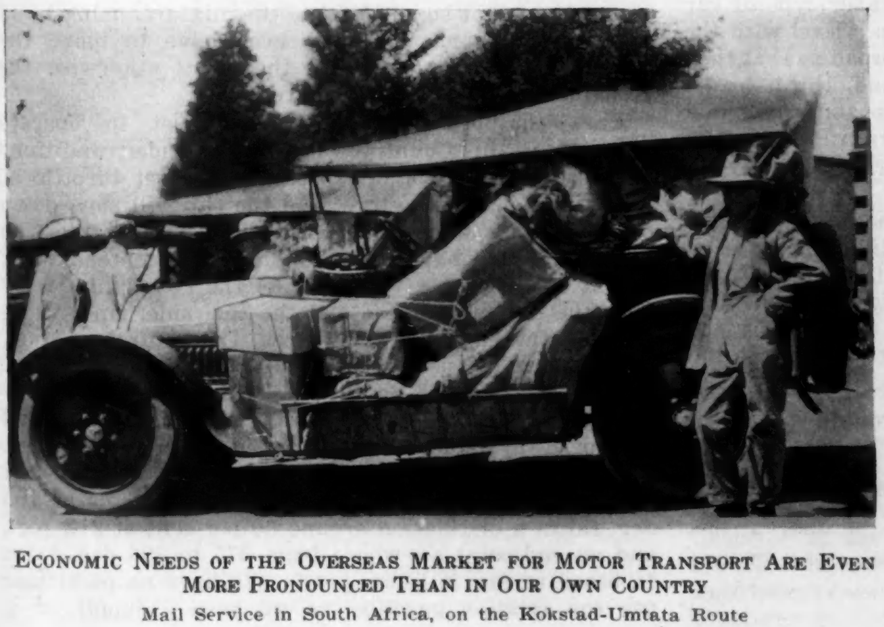
Assuming that we produce a satisfactory light-car and make it available throughout the overseas market, a great number of people, because of their limited incomes, could not avail themselves of even this type of individual transportation. Human beings all have the urge to ride and would do so if satisfactory transportation could be furnished within their means. For this great mass of people we propose organized communal transportation.

Probably all will recall, from earlier days, the practice of four or five workmen joining in the purchase of a low-price car, using it as a means of transportation between homes and plant, and sharing the expense of operation and maintenance. This is communal transportation on a small scale, providing low-cost transportation to a limited few. The taxicab is a form of organized communal transportation, with limited carrying-capacity. Motorcoaches are a form of organized communal transportation on a large scale. Overseas, development of motorcoach transportation is much slower than in the United States.

Great numbers of people throughout the world probably never will be able to enjoy individual automobile transportation, but the need and desire for transportation exist the world over. There are great masses of people—white, yellow, black and brown—who have sufficient income to enable them to ride on a pay-as-you-go basis. So many more people exist in the world today who can afford to ride and to have their goods hauled on this basis than can afford to own and operate individual automobiles, that it seems that the only method of putting the world on wheels rapidly is to provide satisfactory organized communal transportation. By no other means shall we be able within our time to accomplish this.

A big problem in connection with motor-trucks and motorcoaches manufactured in the United States is to deliver them overseas at low over-all cost. It is usually costly enough to get the chassis into the overseas countries. To deliver a complete body, or a complete vehicle, in them at reasonable cost is generally out of the question. Delivering knocked-down bodies is more feasible but not entirely satisfactory. Further effort is needed in the development of suitable motor-trucks for various overseas countries; complete units, including bodies.

If anything is to be done toward providing suitable vehicles for mass passenger-transportation, a great deal



ECONOMIC NEEDS OF THE OVERSEAS MARKET FOR MOTOR TRANSPORT ARE EVEN MORE PRONOUNCED THAN IN OUR OWN COUNTRY

Mail Service in South Africa, on the Kokstad-Umtata Route

of effort will be required in the development of motorcoach units.

The following tabulation sets forth the major principles involved in providing suitable products that will more generally fulfill requirements:

Type of Product	Over-All-Cost Relation	Purchasing-Power Relation
Existing Status Present-type automobile	Has high over-all cost	Use restricted by low purchasing-power
Desired Status Present type, as desired	To have lower over-all cost if possible, on phaeton model at least	Improves purchasing-power relation
Desired Status Light car	To have low over-all cost	Still further improves purchasing-power relation
Desired Status Organized communal transportation	To have low cost of individual ride and haul	Meets need of lowest purchasing-power

THE DISCUSSION

CHAIRMAN F. E. MOSCOVICS[3]:—Mr. Foss referred to the sales of American automobiles going down in four countries; I think they were Germany, France, England and Italy. The sales of European cars were up and the sales of American cars were down. I want to call attention to the fact that in those four countries the tariff is distinctly against American cars. The composite of the other countries, where the duties on American cars are on a parity with competition, shows that the sales were invariably going up.

CLARENCE M. FOSS:—There are other factors, of course.

CHAIRMAN MOSKOVICS:—It was true where there is a parity of duties, notwithstanding the additional cost of transport and other things of that character.

GEORGE L. MCCAIN[4]:—Can Mr. Foss point out some concrete changes or revisions in the motor-car itself that the analysis of the foreign market has indicated to be necessary?

MR. FOSS:—Such changes and improvement as American engineers are now making in cars from time to time to make them better should fit the cars to the overseas market as well as they fit the American market. It is not so much a question of concrete changes or revision of car, or how big or broad it is made; it is more a problem of getting it into the proper price class and the proper operating-cost class.

The three points we made are first, to make the present car a little more available, if possible, by getting the price down; second, to make a smaller type of car that would sell in a lower price-class on a level with the incomes of a large number of people abroad so that they could afford to buy and operate it; and, third, to develop motorcoaches and motor-trucks for communal transportation for another class of persons who cannot afford to own individual cars but can ride on a pay-as-you-go basis.

No definite variations in design or mechanical details are indicated, such as the way the radiator is made or the type of wheels. Some local conditions have to be met, but that is easily done. The basic requirement is to provide automotive transportation overseas on the same economic basis as it is now being provided in the United States.

High-Test Fuels Cause Trouble

LESTER A. GARRARD[5]:—I have been out in the field since 1923, in Japan, China, the Philippines, Java, Siam, the Straits Settlements, but more especially in the Orient. The engineers in America are designing cars and parts and experimenting with some of the conditions we encounter in the practical operations or servicing that will enable the cars to operate properly under the peculiar conditions existing in those countries. For instance, most of the cars are working under sea-level conditions and air temperatures varying from a minimum of about 76 deg. fahr. to a maximum of about 100 deg. There is also a rather wide variation with regard to barometric pressure in comparison with local conditions in the United States, and a wide difference in fuels.

Too Much Heat to Mixture

We have had low-compression and high-compression heads and optional heads; the trend now seems to be all toward high compression. In the United States almost every make of car is using high-compression fuel. In practically all places in the Orient this type of fuel is not available. It costs too much and, even if it were made available, the people do not want to pay the price for it. The regular gasoline costs possibly 40 cents per gal., and they are not willing to add 5 cents or even less for premium or special gasoline.

We find out there under actual conditions that on the latest models of most cars, to get performance, it is necessary in many cases to remove the shields from around the carbureter; we have to take off manifold connections that supply heat to the mixture, using blind gaskets. In some cases we even have to move the vacuum tank up underneath the dash; otherwise the gasoline will boil in the carbureter.

Cars equipped with thermostats set to operate promptly in this Country, when driven under conditions over there at a constant speed or with set throttle at say 25 m.p.h., often surge, and the car will slow down on account of too much heat to the mixture. We who are in the field have those conditions to contend with, and it has been my luck to take the complaints from both the automobile side and the fuel side, since there are very few engineers out there. The natural reaction, if the car is not performing properly, is to believe that the fuel is at fault. Because of local petroleum production, we have to use certain fuels that are available and are not always able to change the fuel because of prices. These fuels invariably are what we call here high-test gasoline, having an initial boiling-point possibly of 105 deg. fahr., a distillation around 30 per cent at 212 deg., and an end-point anywhere from 375 to 396 deg. fahr. In other words, it is too good. We have no particular use for aviation gasoline, so we have a supply of it

[3] M.S.A.E.—President, Stutz Motor Car Co. of America, Inc., Indianapolis, Ind.

[4] M.S.A.E.—Research engineer, engineering department, Chrysler Corp., Highland Park, Detroit.

[5] F.M.S.A.E.—Sales engineer, Standard Oil Co. of New York, Manila, P. I.

that we use as motor gasoline. Consequently, on the ground we have to cut out all the heat we can, and when we do so we gain on the average about 4 miles to the gallon, with about 2 sec. quicker acceleration from 5 to 35 m.p.h. In many cases drivers operating cars or trucks on grades are not able to get up because the mixture apparently expands too much and the cylinders do not get a sufficient charge.

Another trouble encountered is wood rot. In the tropics wood is subject to dry rot, which means that in from 16 to 18 months the usual automobile body has to be torn down and either partly or completely rebuilt in the wooden parts, which is an expensive operation. So generally, while the things that are applicable here are also applicable out there, we have many freakish, peculiar conditions. If they can be considered and provided against, we may be helped a great deal.

Cooperation Solves Fuel Difficulty

KIRKE K. HOAGG[6]:—We found much the same sort of condition as Mr. Garrard described when we first went into certain territories. I came back recently from one of the territories mentioned. Most of the fuel sold was high-test gasoline, and there were the natural difficulties with a fair amount of heat on the manifold. Because of the mechanical trouble involved, it was thought best not to try to re-engineer the cars, which is something we have to combat in most of the far-flung territories.

We got together with the fuel supply people and discussed the type of fuel that American cars were being designed to utilize, which happened to be a type that was in the market only in small quantities. By securing cooperation from the fuel-supply companies, we reversed that position and shortly thereafter three-quarters of the fuel sold was low-test gasoline. We supplemented this with a campaign of education of the dealers and from them to the car owners. This relieved those handling American cars of many of the troubles involved in carbureter adjustment, changing jets, and regulation of the amount of heat on the manifold.

I think wherever American cars are beginning to predominate in any market we shall have no difficulty for any length of time with fuels if some such course is followed.

Volume Sales-Low Price Problem

NORMAN G. SHIDLE[7]:—Mr. Foss has suggested that if the American manufacturer is to get volume sales in foreign countries he will have to have a light car that he can sell to the small-income class. What is Mr. Foss's opinion as to the practical possibility of successfully manufacturing such a car for sale primarily if not exclusively in the foreign market?

The success of the American car so far apparently has been due largely to the fact that it was built primarily for American conditions and thereby quantity production was attained. Incidentally, because of the quantity production for the American market, it was possible to make the price low. Any kind of a light car so far has been quite unsuccessful in the United States, because we have low-priced full-size cars. Therefore, if an American manufacturer built a light car that could be sold at a low price in a foreign country, do you think his chances of getting large sales would be good in the United States? If not, is it feasible for him to manufacture that car exclusively for the foreign market?

MR. FOSS:—We put it another way: If a manufacturer in the United States wants to meet the needs he must make a light car. We have tried to point out the basic economic requirements. Now we have high over-all cost of cars in the overseas market. That does not mean only American cars, but all cars. We have, secondly, the lower purchasing power of the prospective buyer in overseas markets. The price is up and the pocket-book is thin.

In the United States we have just the reverse: the highest purchasing-power relation of any country in the world and the lowest cost of automobiles from an over-all standpoint; we have produced the type of car here that meets the economic requirements.

I cannot say at this time how many cars one should build or how to build them to meet the economic requirements overseas. The requirements are basically for low-cost automotive transportation. We simply say to build another type of car to meet the fundamental requirements of the lower price-class. The problem presented is for the engineer to design and the manufacturer to build a car to meet the requirements as outlined.

MR. SHIDLE:—What I really was asking for was your opinion as to whether it is possible to develop this light car. I realize you cannot answer the question definitely.

European Light Cars Selling Overseas

MR. FOSS:—It is being done to an extent today. Light cars made in the four manufacturing countries of Europe are being sold and operated throughout the world alongside of the present type of automobile that comes from America or from Europe. Anywhere you go—Australia, South Africa, India—you will find this light type of car. The large production in the four manufacturing countries of the overseas market is in this light type of car. That is an indication and an index.

In the United States today we do not have a car in the true low-price class. Four or five years ago we had one at $260, but we do not have it any more. Have we all become so rich in this Country overnight that we cannot put a car on the market in a lower price-level that would be attractive to the buying public?

BURTON J. LEMON[8]:—What is the demand in the foreign field for tires? Is it for four-ply or six-ply, and, if six-ply, what is the reason?

MR. FOSS:—That is a matter of detail that we would have to go back to the statistics to get information on. I do not know off-hand.

Qualities the Light Car Must Have

HOWARD K. GANDELOT[9]:—Do you think the export buyer would be willing to sacrifice the appearance, particularly of the smaller cars, and accept lower-price trim and lack of plating on the exterior surfaces; and would that favor the possibility of the American manufacturer building an extremely low-priced automobile

[6] M.S.A.E.—Engineer, General Motors Export Co., New York City.
[7] M.S.A.E.—Directing editor, Chilton Class Journal Co., Philadelphia.
[8] M.S.A.E.—Field engineer, tire development department, United States Rubber Co., Detroit Plant, Detroit.
[9] A.S.A.E.—President, general manager, Howard K. Gandelot, Inc., Minneapolis.

for the export trade? In the gathering of facts for the compilation of statistics, do they show that any foreign manufacturers have sacrificed appearance and quality to cut the price down and get the business?

MR. FOSS:—This light car must be low in first cost; it must have low operating cost; it must have appearance; it must have comfort; and it must have the proper performance. Cars today, whether they are American or European, light or heavy, are sold largely on appearance. Just set down appearance, comfort, price and performance and you have, in their relative positions, very nearly the main points on which cars are sold.

CHAIRMAN MOSKOVICS:—Some years ago I was asked to investigate one of these cars in one of the foreign countries and it had just about the things Mr. Foss mentioned. I should say that the driver had to shift gears going over a manhole cover. I do not know what the standard of performance was, but I did not think it would get very far in America.

V. P. RUMELY[10]:—Has any progress been made toward standardizing the customs and regulations of the various countries? I have in mind some of the peculiarities that confront manufacturers. For example, there actually is one country which, if a chassis is knocked down—as it should be for economical shipping, and incidentally the workmen in that country are given the opportunity to perform labor on it—actually charges a higher duty than if it is sent in built up.

MR. FOSS:—Tariffs are one of the barriers in getting cars from this Country into the other countries. There is no standardization, I can assure you. There cannot possibly be standardization until the countries get together and all are willing to agree on a common schedule.

[10] M.S.A.E.—General stores manager, Hudson Motor Car Co., Detroit.

Landing-Room an Aviation Need

AVIATION in America, measured in terms of aircraft factories and airplanes in operation, very greatly exceeds the aggregate of the rest of the world. This development has taken place without Government subsidy and in the typically American manner of private enterprise. Commercial air-transport has reached its present comparatively satisfactory state without the hundreds of millions of dollars that the railroads enjoyed from Federal and State aid in their pioneering days, and without the hundreds of millions of acres of lands granted to them.

There is, however, a growing need for indirect assistance by the Government, particularly in airports. That the fulfillment of this need is neither impractical nor expensive is indicated by the fact that 3 per cent of the area devoted to railroads and roads in this Country would provide a comprehensive system of landing-fields for aviation.

Today only two outstanding factors are holding back safe and universal flying. One is a technical problem; namely, the loss of control due to the breakdown of the airflow over the wings of an airplane at low speed. The solution of this problem is imminent, if it has not already been solved. The other problem is a simple one, in fact so simple that, like many obvious matters, it has been neglected; that is, the provision of adequate terrain for the airplane to land on wherever it may be and whenever it may be necessary.

If airports were located throughout this Country at intervals of 10 miles in each direction, an airplane would normally never be more than 5 miles from a landing-field, or, in other words, would rarely be out of gliding distance, if flying at an altitude of 4000 or 5000 ft. The amount of land which this would require is insignificant in comparison with the area devoted to the railroads or roads of the Country.

It is roughly but conservatively estimated that the total land occupied by railroad right-of-way in use and by station property is 21,550 sq. miles. The total area occupied by the Nation's highways, according to the latest mileage and allowing a conservative width of 50 ft., is 28,500 sq. miles. As against these areas amounting to a total of 50,050 sq. miles, landing-fields of normal intermediate size—1200-ft. runways, as used by the air mail—placed 10 miles apart all over the Country, would require only 1544 sq. miles, or about 3 per cent of the other figure.

Even if we consider an airport of the maximum size set by the Department of Commerce—with 2500-ft. runways in all directions—this would require an area of only 6720 sq. miles devoted to air transport, as compared with the 50,050 sq. miles given over to highways and railroads.

The smaller area of 1544 sq. miles would adequately care for the airplane's requirements as it exists today, without consideration of wheel brakes and other developments in airplane design and construction which are greatly reducing landing runs, and therefore the field lengths needed. Looking forward just a little in aviation, we can visualize the reduction of this total landing-field area to insignificant figures. For example, in the Fund's Safe-Aircraft Competition, one of the conditions for qualifications is that the plane shall glide into the field over an obstruction 35 ft. high and come to rest within a distance of 300 ft. from the base of the obstruction. There seems to be little doubt among eminent designers and constructors that this condition will be met.

If we assume landing-fields 400 ft. square, only 171.6 sq. miles would be required for landing-fields 10 miles apart over the entire Country.

One has but to fly over even the most thickly populated areas in the East to realize how comparatively easily and cheaply land could be made available for a Nation-wide system of landing-fields. Following close on the heels of the realization of such a system, flying would be the safest means of rapid transportation and become universal in America, with its concomitant economic and social advantages. America's great resources and huge undeveloped territories should make the inauguration of such a plan of special appeal to Americans.—Harry F. Guggenheim.

Fleet-Maintenance Practices

Maintenance methods followed by two organizations operating motor-vehicle fleets are outlined by W. M. Clark and John H. Walsh in the following papers, which were presented at a meeting of the New England Section. Operation and maintenance requirements are treated by Mr. Clark, and motorcoach operation is described by Mr. Walsh. An abstract precedes each paper and also the discussion, which applies to both.

Operation and Maintenance Requirements

By W. M. CLARK[1]

OPERATION of a fleet of motor-vehicles can be built up only on proper and intelligent maintenance, and neither the operation nor the maintenance department can be successful unless each is built up with an understanding of the other department's problems, the author contends.

The methods of maintenance are determined by whether the vehicles are localized or scattered, and upon the regular and the peak demands for given periods. The method adopted should influence the type of vehicle selected. Unless provision is made to secure accurate data on costs, the best efforts toward satisfactory maintenance are largely futile; but cost data should be only a means to an end, not the end itself.

Discussing fleet maintenance from the viewpoint of resulting costs rather than from that of keeping the wheels turning, a tabular statement of the division of expense, expressed in percentage, is presented, and reasons are given for the grouping of the various items. A statement is given also of the division of labor per vehicle per year, and comments are made thereon. Repair labor, the largest single item of expense, is analyzed under the headings of current repairs, "campaigns," inspection and detailed overhaul, and rebuilding. In conclusion, brief reference is made to record keeping and stock kept for servicing purposes.

SUCCESSFUL maintenance of a fleet is more than a matter of keeping vehicles in operating condition. Definite requirements of both maintenance and operation must be clearly analyzed, considering them as links in the chain of departments, and the result is a compromise. It may be argued that this analysis of the relation of the vehicle fleet to the business is a factor of operation rather than of maintenance, but it is my contention that operation can be built up only on proper and intelligent maintenance, and that neither department can be successful unless each is built up with an understanding of the other department's problems. From the viewpoint of operation alone it would be ideal to make up a fleet in which each vehicle specifically fitted its particular route as to size, speed and power; and from the maintenance angle only a fleet composed of vehicles of the same type and size would be most desirable. Thus the compromise that must be made is evident.

Methods of maintenance are determined by two main factors; whether the vehicles are localized or scattered, and upon the regular and peak demands for given periods. Scattered location and seasonable peak-demands lead to the method of making nominal current repairs and instituting periodic overhauls; close location and steady operation tend toward a maintain-as-you-go policy. The method adopted should influence the type of vehicle selected. Some fleets include all conditions, and both methods of maintenance can be combined to provide the desired steady flow of work through the maintenance department. The most maintenance with the least maintenance work and at the least possible cost is the objective sought.

Unless provision is made to secure accurate data on costs, the best efforts toward satisfactory maintenance are largely futile. But cost data should be a means to an end, not the end itself. Despite the lack of uniformity in all details, a general similarity exists in most systems of motor-truck accounting as to the main items of expense. The expenses for which all maintenance men are responsible are: storage and garage, gasoline, oil, chassis-repair labor, chassis-repair material, painting and body repair, and tires. I shall consider fleet maintenance from the viewpoint of resulting costs rather than from that of keeping the wheels turning.

Division of Expense

To present a true picture of maintenance conditions, we should be able to separate those expenses that depend on the mileage covered by the vehicles from those that have no relation to mileage. Therefore the non-mileage expenses in Table 1 are grouped as storage and garage expense, and represent one-quarter of the total expense.

The headquarters for any type of maintenance selected must provide space for the various maintenance operations, for the storage of parts and materials, and for those vehicles that require housing. The type of building required in metropolitan areas for garage and repair-shop purposes is of expensive construction. Every square foot of space requires light, heat and care. The necessary requirements of the fleet must be

[1] M.S.A.E.—Superintendent of transportation equipment, S. S. Pierce Co., Boston.

analyzed carefully before going ahead with the building program. For the average fleet, many of the facilities can be combined to advantage. Under average operating conditions the vehicles will require housing for a part of the day, and a combination of shop, loading and warehouse space tends toward economy. The trend toward this type of building is very marked, and I shall relate some experiences with this type of layout as it affects maintenance operations.

Most of the combination layouts have been designed for delivery fleets, such as those for department stores, where it is desired to have the vehicle backed against a platform ready for loading. The vehicle is backed into place by the driver at the end of his day's work; washing, greasing and minor repairs are done while the vehicle is in place. But washing vehicles under these conditions is far from satisfactory, because working space and good light are necessary and neither is available when the vehicles are crowded together at a loading platform. Washing in place leaves a wet dirty floor for the greaser and the repairman to work on, and in cold weather it handicaps the workmen. Minor repairs begun on a vehicle while it is in place often develop into jobs requiring much running back and forth for stock and tools, and often necessitate removing the vehicle to the shop.

The best results are obtained by inspecting each vehicle after it has finished its day's work and sending it for washing, repair work and greasing to a designated space where suitable facilities are provided, returning it later to the loading platform. Location of the shop department as close to storage space as possible is desirable, but the location of the shop in a separate building is to be avoided for fleets of this type. Possible savings in construction costs warrant a careful layout of operation methods by the maintenance superintendent so that he can convince the company's executives as to what constitutes desirable building practice.

Division of Labor

Table 2 gives the total number of hours of labor per vehicle per year for the items shown. The use of a power-driven pump for washing the vehicles saves time and helps to keep them in better condition. Our greasing schedule is based on a time rather than on a mileage basis. I do not question that, considering the labor of greasing alone, it costs more than if it were done on a basis of maximum mileage between greasings; but, to offset this, there is the clerical labor of checking the mileage per vehicle and the likelihood of excessive wear and failure because of error or neglect to grease at the scheduled mileage. Considering the cost of the parts that greasing protects, it even is justifiable to duplicate greasing to assure the elimination of wear. On account of improved design, it is possible to extend the time of greasing the major components, such as the axles and transmissions, and, where the mechanical inspections are close together, to combine greasing them with the inspections.

TABLE 1—DIVISION OF EXPENSE, PER CENT

Storage and Garage			25.8
Building		8.6	
Rent, Light and Heat	6.7		
Labor	1.0[a]		
Supplies	0.9		
Service and Clerical		6.9	
Washing		2.7	
Labor	2.57[a]		
Supplies	0.13		
Oil and Grease		3.4	
Labor	2.92[a]		
Grease	0.48		
Soap and Supplies		1.7	
Outside Storage		2.5	
Gasoline			15.5
Oil			2.6
Repair Labor			22.3[a]
Repair Materials			13.3
Paint			3.8
Tires			12.0
Miscellaneous			4.7
			100.0

[a] Total Labor=28.79 per cent.

TABLE 2—DIVISION OF LABOR PER VEHICLE PER YEAR

	Hr.
Building Labor	24.00
Pumping Gasoline and Filling with Oil	10.25
Greasing and Changing Oil	44.30
Washing	54.50
Repair Labor: Motor-Trucks	234.00
Repair Labor: Passenger-Cars	76.00
Tire Maintenance	27.00

It is rather surprising that more progress has not been made in the redesigning of such parts as spring shackles, axle pins and parts that require a weekly greasing, and that the one-shot system of greasing has not been generally adopted, since the saving in labor cost seems to warrant factory installation of such a system. Our yearly cost of greasing is $27 per truck for labor alone, and two-thirds of this cost is for greasing parts that could be greased by a one-shot system at an initial factory cost of $100 for the most extensive type, which would be well worthwhile when the length of time over which trucks are operated is considered. We try to apply production methods to greasing and to our maintenance problems in general. The first five nights of the week are devoted to greasing with a grease gun, and a certain part of the fleet is covered each night. Saturday nights are left free for greasing operations that come at longer intervals, such as monthly or every second month.

Gasoline and oil are charged to the particular vehicle when they are given out. Space is also provided on the form to record the odometer reading, and this is done each night. For the benefit of the operation department, which is charged each day for the mileage the trucks cover, the garage office furnishes the mileage of each vehicle for the previous day. This is done at the time the gasoline and oil and odometer readings are entered in the monthly record, and hence the consumption can be checked against the mileage.

Repair Labor

The largest single item of expense is repair labor. I shall consider it under the headings of current repairs, campaigns, inspection and detailed overhaul, and rebuilding.

A certain amount of current repairs is necessary under any system of maintenance. A driver's report covers minor repairs that are needed and, in most cases, the work is done at night. Our method of lubrication is along production lines. Vehicles of one kind are greased the same evening, and the transmissions and universal-joints are all greased at one time.

Every type of vehicle has certain maintenance needs that can be most easily and surely covered by what we term "campaigns." We set aside certain nights for going over every vehicle of a particular type. Some of the campaigns are for tightening universal flange-bolts and spring clips, for inspecting clutch-pedal adjustment, brake adjustment, lights and curtains. Others are for oiling overhead-valve lifters, inspecting fire extinguishers, general tightening, and inspections for appearance.

Periodic Inspection

The time for periodic inspections usually is based on mileage operated by the vehicle. It varies with the kind of vehicle and the operating conditions, and is determined by experience. We have tried various mileage periods from 2000 to 5000 miles and, except for a few vehicles, have settled on 3000 miles as being most satisfactory. In some fleets, most of the lubricating is done at the time of periodic inspection. We do a great deal of unit-replacement work at these inspections; in fact, some of the trucks that are several years old have not yet been torn down for general overhaul. With other trucks, the work done at the periodic inspection is lighter, and the major operations are performed after longer periods.

We have found it advisable to break the repair crew into units of two men for inspection work on each vehicle. Our medium-sized vehicles average 30 hr. of labor per vehicle per inspection. With two men to a vehicle, the vehicle averages two shop days for each 3000 miles. We have been able to lay out an advance schedule of maintenance by considering the mileage that will be covered during a period and the required number of hours per inspection. By this means we can plan on the number of men required. For example, we have 20 vehicles of one make that cover an average of 1200 miles per month. Dividing this 24,000 miles per month by 3000, the mileage period, gives eight inspections per month. With 30 hr. required per inspection, we have a total of 240 hr. of labor for inspections per month for this group.

Formerly, we had an inspection form which listed everything from the starting crank to the tail-lamp. Each man was assigned a certain section of the form and was supposed to cover thoroughly every item. But recently we inaugurated a bonus plan on repairs, and with this adopted a job order in place of the inspection sheet. The foreman now makes out the job order, going over the vehicle somewhat in the order of the former inspection sheet. Our road troubles following an inspection job have now decreased, and the job order is a better record of the work done. For small jobs and for details of the work on the job order, the time card is used. As this carries a record of the stock used, it is a sort of double check as well as a record. We use the job tickets for small jobs. These serve as a record of the work done, the workmen can protect themselves, and we can trace the work back to individuals, all on the same record. The costs of labor and material for individual vehicles are summarized monthly.

Material

Material is listed on perpetual-inventory cards so that, after maximum and minimum quantities have once been established, reordering becomes automatic. The day and the night foremen charge the stock directly on the workmen's time-cards. When the stock clerk checks the perpetual inventory, if the same part is charged twice, it is caught. If parts that go with the job are not charged, this is also caught. As we are close to sources of supply, we carry the minimum amount of stock, sacrificing on quantity prices at times. On Oct. 1, 1928, we had $254 worth of stock for the servicing of 30 small cars; $76 for 10 of another make; $720 for 20 2-ton trucks; and $3,700 for a fleet of 40 3-ton vehicles, about half of which amount was for assemblies. The charges for stock are entered on individual stock-cards. Tire expense amounts to 12 per cent. On no part of the expense can a greater proportion of saving be made by means of thorough care and accurate records than on tire expense. We find it more economical to have painting and body repairs done commercially outside of our organization.

Motorcoach Operation

By JOHN H. WALSH[2]

METHODS practised in operating and maintaining a fleet of 82 motorcoaches, distributed among garages located in five towns, are described. Regularity of service is regarded as of paramount importance by the author, who states that it is imperative to take every precaution to prevent the premature failure of the mechanical and the electrical equipment.

The inspection methods in force and the procedure for major overhaul of the vehicles are described. Machines specially adapted to enable the mechanics to perform repairs effectively and to reduce the time required for repairs to the minimum are included in the shop equipment. Equipment is also provided for reclaiming used lubricating oil. Unit replacement is a feature of the repair work. Fast-drying lacquer is used extensively in refinishing coach bodies.

TRANSPORTATION furnished by the Middlesex & Boston Street Railway Co., in Middlesex County, Mass., serves Newton, Waltham, the Wellesleys, Natick, Lexington, Arlington, Concord and Billerica. Our fleet comprises 82 motorcoaches equipped with four-cylinder engines, and 47 have air brakes. The fleet averages an aggregate of 8000 miles per day, 215,000 miles per month, and more than 2,500,000 miles per year. We use 1000 gal. of oil and 32,000 gal. of gasoline per month, and average 6 miles per gal. of gasoline.

The vehicles are distributed among five garages; 41 at Waltham, 18 at Auburndale, 12 at Lexington, 7 at Natick and 4 at Hopkinton. In each of the garages, excepting that at Hopkinton, are stationed a foreman and

[2] Superintendent, rolling stock and shops, Middlesex & Boston Street Railway, Waltham, Mass.

such mechanics as are needed to perform the required inspection and repair work and to change units other than engines. One mechanic only is employed in the Hopkinton garage.

Our general repair shop is located at Waltham, and all repairs, including body repairs and repainting, are made there. In our general stockroom at Waltham we carry about $12,000 worth of renewal parts of all descriptions, and this aids materially in expediting necessary repair work.

Regularity of service in the transportation business is most important. For example, consider a passenger who, in good faith, goes to a street corner to board a motorcoach that is due on the hour. He looks up the street for a while, waits and frets and fumes for 15 min., and then boards the next coach, the driver of which informs the angry passenger, who very likely has missed an important engagement, that the other coach had a broken fan-belt. In such a case the company loses the good-will of the passenger, who probably tells the story many times to friends. It loses also many other passengers who were forced to walk to their destination. With the possibility of such far-reaching effects for a single delay, it is imperative that every precaution be taken to prevent the premature failure of the mechanical and the electrical equipment. Only after making service as reliable, fast and comfortable as possible, can we hope to sell transportation to the best possible advantage.

Inspection and Overhaul Methods

The coaches are cleaned inside and out daily, and a vacuum cleaner is used once a month. Inspections of tires, body and running lights are made daily. After 1500 miles of operation, each coach is given a test run of about 1 mile by an inspector who is competent to judge any imperfections in the mechanical and the electrical equipment. Following this, a general inspection is made of the chassis, and all moving parts are lubricated. The wheels are aligned, the brakes adjusted, and the front end and the steering-gear inspected. Drivers are required to turn in a "defect form" every night, on which they record anything unusual about the vehicle's performance during their 9-hr. working-period. These defect forms are deposited in a box at the garage, and necessary repairs are made by the night mechanic.

A general overhaul after approximately 55,000 miles of operation is our practice. Although we have two coaches each of which has operated 80,000 miles without having had piston-ring changes or other work of this nature performed, we feel that the average for our fleet will never reach more than 60,000 miles as an overhaul period. It is not our practice to perform any so-called "ring jobs." After running from 55,000 to 60,000 miles, a coach is dismantled, the engine block is sent to an outside shop to be re-bored, while our shop performs any necessary work on the bearings, timing gears, camshaft and other parts. Afterward, new piston-rings, pistons and piston-pins are fitted.

Shop Equipment

To enable our mechanics to perform repairs effectively and to reduce to the minimum the time required for repairs, we have installed machines specially adapted for this work. These include a main-bearing bar, a connecting-rod fixture, a bearing trimmer, complete valve-repairing equipment including a valve refacer, an engine test-stand, and all sorts of special drills and grinders. We carry in stock a large number of spare electrical units such as generators, magnetos and starters, and also complete rear-ends, transmissions, and the like. It is not our practice to change the rear end and transmission at the time of an overhaul unless our records show that these units have accumulated sufficient mileage to warrant their change. All electrical equipment is dismantled and thoroughly tested at the time of general overhaul. Equipment is also provided for reclaiming used lubricating oil.

Refinishing and Repainting

Fast-drying lacquer is used extensively in refinishing coach bodies. Seventy-five of our coaches are lacquer finished. As an example of the effectiveness and wearing qualities of lacquer, one of our coaches was in service for 25 months and ran 58,000 miles, after which it was brought in for a general overhaul. The outside finish was cleaned and polished at a cost of $7 and, when finished, would pass anywhere for a new job. This is not an exceptional case. We have followed this practice extensively since that time and expect, by this method, to get at least four years of service from the coaches having exterior lacquer finish; the inside of the body is refinished and enameled every two years. In the everyday cleaning of motorcoach exteriors that are finished with lacquer, the surface can be readily cleaned solely by the use of hand power and soft-cloth rags.

As an aid to furnishing the required number of motorcoaches for peak headways, we stock outside body-panels, all of which have been refinished up to the color coat. It is therefore possible to replace a damaged panel with a new panel, completely refinished, within 2 hr. Another satisfactory feature in using lacquer is the closeness with which it is possible to match the shades of color.

In conclusion, I believe that any method, machine or tool that will aid in reducing the mechanical failures should be put to use, so that breakdowns of whatever nature can be reduced to the minimum in all fields of transportation served by motorcoaches, motor-trucks and taxicabs.

THE DISCUSSION

PROCEDURE with regard to charging-out stock is outlined, and the details of greasing the vehicles are given. For the fleet of 82 motorcoaches, it is stated that the cost of operation over a period of about four years has been from 27 to 30 cents per mile.

QUESTION:—Why is the greasing schedule based on time rather than on mileage?

W. M. CLARK:—Mainly for reasons of safety.

F. W. HERLIHY[3]:—Is charging-out of stock on a mechanic's time-card supplemented by a requisition, and is the perpetual-inventory record made from the time card?

MR. CLARK:—The day and the night foremen pass out stock and supplies. These are entered on the time cards and are posted from these cards to the perpetual-inventory record. When the stock reaches the minimum quantity allowable it is re-ordered. The foremen are qualified to judge whether stock should be ordered for purposes specified by the mechanic, and whether new

[3] A.S.A.E.—Superintendent, bus division, United Electric Railways Co., Providence, R. I.

parts should be substituted for old ones. The part number and designation are posted on each bin, and a complete stock-index is available so that a mechanic can specify the part number.

QUESTION:—Is it your practice to remove grease completely between overhaul periods and to flush the parts?

MR. CLARKE:—If the grease appears lifeless it is removed, the parts are flushed, and new grease is substituted.

QUESTION:—What type of men are employed for doing greasing work?

MR. CLARKE:—One man is made responsible for greasing and is made to feel his responsibility and the importance of this work. He is provided with a helper.

MR. HERLIHY:—In our shop, greasing is done by a first-class mechanic's helper. He is convinced of the importance of this work, so that he makes it almost equivalent to an inspection.

[4] Legislative counsel, Boston.

QUESTION:—What method is used to secure accurate alignment for front wheels?

JOHN H. WALSH:—We use an extension-rod device furnished by the manufacturer, and check wheel alignment after 1500 miles of operation.

QUESTION:—What success has attended the use of heating with hot-air devices in motorcoaches?

MR. WALSH:—They are largely unsatisfactory. The passengers near the front of the coach get all the heat.

DAY BAKER[4]:—Eight motorcoaches were burned in Massachusetts during a period of 16 months, the fires being caused by the contact of celluloid umbrella-tips with the heating devices. Some protective device should be installed to eliminate this serious menace.

QUESTION:—What is the cost per mile for operating motorcoaches?

MR. WALSH:—Our vehicles stop very frequently and operate in low gear much of the time. Over a period of about four years, the cost of operation has been from 27 to 30 cents per mile.

Spinning Characteristics of Airplanes

(*Concluded from p. 478*)

surface of almost 75 to 100 per cent, because the slot actually would act as a front slot with flap, in which case the elevator would act as the flap.

While high angles of attack are ordinarily a hindrance in the use of the front slot, the effective angle of attack of the tail is high in spinning, thus presenting another advantage in the use of the automatic slot. It may be desirable to provide the front auxiliary airfoil with a simple locking device, so as to be able to resort to the front-slot action only in case of urgent necessity.

Conclusions

I believe that we do not possess today definite data which would enable us to design airplanes incapable of dangerous spins; nor do we know of any means which would assure a certain recovery. Now and then an unhappy combination of factors beyond our control, such as mass distribution, results in a design that displays dangerous spinning characteristics. It remains for systematic investigation and experimentation to equip us with more definite facts that will enable us to predict the characteristics of this particular motion of airplanes.

In the light of the available data it seems, however, that to prevent an incipient spin the following characteristics are of paramount importance:

(1) Wing combination having no sudden drop in lift past the burble point
(2) Ample lateral control by proper design of the ailerons and preferably by use of the automatic front slot. The Freeze type of ailerons is desirable. This point is not generally agreed upon
(3) Location of the center of gravity so as to give correct static stability for normal flying-speeds
(4) Proper disposition of vertical and horizontal tail-surfaces. Rudder and fin areas below the fuselage are desirable. The rudder must be effective for small displacements

To assure recovery from a dangerous flat spin, the first of the enumerated conditions seems to be detrimental but the following characteristics were found desirable:

(1) Large rudder-area
(2) Small body cross-section near the tail
(3) Large aspect ratio of the tail and powerful elevators
(4) Disposition of control surfaces as in flying-boats is generally believed desirable
(5) The center of gravity should not be located abnormally far back. The desirable location is not farther aft than 36 to 37 per cent of the mean aerodynamic chord

The spinning of airplanes presents a complex problem the study of which is handicapped by the limitations of wind-tunnel equipment and the individuality of behavior of various airplanes.

It is futile for a designer to attempt, with our present knowledge, to resort to any mathematical treatment of the problem. Our hopes lie in the inventiveness of the engineer, the insight of the scientist and the resourcefulness of our research institutions. These will succeed.

Automotive Research

Lubricating-Oil Specifications

Why S.A.E. Number System Relates to Viscosity and Does Not Specify Oil Properties

MOTOR-VEHICLE operators have for some time been incessantly demanding lubricating-oil specifications that will describe fully the product desired so that the manufacturer can supply it and the purchaser can determine whether the product supplied has the desired properties. Such a plea was voiced before a meeting of the Service Managers Forum of the National Automobile Chamber of Commerce by P. V. C. See, superintendent of equipment of the Northern Ohio Power & Light Co., of Akron, Ohio. Mr. See aptly expressed the situation of motor-vehicle operators in regard to this matter as follows:

We are purchasing our oil for a fleet of 215 motorcoaches under specifications which give flash, fire, and two viscosity points, also the amount of carbon. It seems as though these five points do not give any definite check on the quality of the oils.

One of the greatest services that could be rendered to the operator would be to draft an oil specification that would definitely specify the lubricating oil. The Government has supplied us with a very definite gasoline specification that enables us to buy in the open market and be sure of getting the quality we desire; whereas, when we purchase lubricating oil in carloads under specifications, we receive bids ranging from 16 to 50 cents per gal. on oil which will meet our specifications.

Difficulties of Drawing Specifications

Extensive research has brought about an appreciation of the many difficulties involved in arriving at any such specifications. The problems encountered were well summed up by George A. Round, of the Vacuum Oil Co., at a recent meeting of the Metropolitan Section of the Society. In concluding he said:

The longer I work with lubricating oils the more I believe that specifications have their limitations—they do not tell the whole story.

As evidence supporting his own conclusions, Mr. Round quoted from the Report of Committee D-2 of the American Society for Testing Materials entitled, The Significance of Tests of Petroleum Products.[1] The following extracts from the proceedings of the A.S.T.M. give the opinion of this committee on the value of certain tests which have hitherto been regarded by many as indicative of oil quality, and give an authoritative answer to the question raised two years ago by Mr. See as to the significance of flash, fire, viscosity and carbon tests.

Flash.—For a large number of petroleum products, notably the class of lubricating oils, flash-point is not determined as an index of fire hazard but rather for purposes of identification and classification. The interpretation of figures is not simple and as a general rule it may be said that the flash-point of a lubricating oil bears no direct relation to its usefulness. Flash-point tests are useful to refiners in controlling the manufacturing process. The usual practice in writing specifications is to attempt to identify certain types of oils which are known through experience to be suitable. Existing methods for determining the actual usefulness or value of lubricating oils are not satisfactory, and in general it may be stated that the use of flash-point limits in lubricating-oil specifications is actually a makeshift to compensate for a large factor of ignorance.

Fire-point.—The whole question of fire-point can be summarized by the statement that knowledge of this physical property adds little to the information that can be obtained from flash-point figures.

Carbon Residue.—The carbon-residue test was originally developed for comparison of the carbon-forming properties of lubricating oils for internal-combustion engines. It is frequently claimed that the quantity of carbon deposited in cylinders and on pistons is proportional to the carbon residue of the oil. Under ideal conditions this is probably true, but with average operating conditions, other factors, such as the viscosity of the oil, the mechanical condition of the engine and the conditions of carburetion of the fuel, may dominate in controlling carbon deposition.

Viscosity.—For lubricating oil viscosity is the most important single property. In a bearing operating properly, with a fluid film separating the surfaces, the viscosity of the oil at the operating temperature is the property which determines the bearing friction, heat generation, and the rate of flow under given conditions of load, speed, and bearing design. The oil should be viscous enough to maintain a fluid film between the bearing surfaces in spite of the pressure tending to squeeze it out. While a reasonable factor of safety is essential, excessive viscosity means unnecessary friction and heat generation.

These points are only a few of the characteristics that might be included in specifications. Other tests, such as gravity, pour-point, color, emulsion and acidity, are frequently designated but, according to the conclusions of Committee D-2, these are equally inadequate as an indication of the performance value of oil.

Schmidt Comments on Specification Writing

M. R. Schmidt, of the lubrication department of the Standard Oil Co. of Indiana, in a paper[2] presented at the Semi-Annual Meeting of the Society in 1927, discusses the manner in which specifications usually originate. One method followed is to analyze a satisfactory lubricant and embody the results in the specifications, but the specifier does not know that the product is the best for his purpose and does not possess the facilities for accurate analysis and the ability to determine the pertinent from the irrelevant factors. Another method is to select from a number of analyses and specifications items that seem important and incorporate them in the writer's specification. The result calls for a non-existent hybrid that may be impossible to produce. A third method, and the only proper one, according to Mr. Schmidt, is to make a comprehensive study of each lubrication problem and summarize the results in the specifications. He states:

When such studies are made, it will often be found that narrow limits of viscosity, flash-point and other features are not necessary in oils, and that exact soap-percentages, oil viscosities and consistencies are not essential in greases. Moreover, service tests will reveal that good lubricants frequently possess characteristics which cannot be expressed in figures or otherwise reduced to writing.

Mougey Comments on Schmidt Paper

H. C. Mougey, Vice-Chairman of the Society's Lubricants Division, while agreeing with Mr. Schmidt that it is desirable to have specifications covering the important properties of oils determined from the standpoint of use, points out the difficulties encountered in drafting specifications based on either broad or narrow limits, because of vigorous objections raised by the oil companies. Mr. Mougey's comments were prepared at the time Mr. Schmidt's paper was presented but arrived too

[1] See *Proceedings of the American Society for Testing Materials*, vol. 28, 1928, p. 479.
[2] See THE JOURNAL, June, 1927, p. 750.

late for inclusion in THE JOURNAL with the paper and are printed here for the first time.

H. C. MOUGEY:[3]—The writing of oil specifications is a relatively new art for many people, and no doubt time will remedy many of the difficulties existing at present. However, several items which Dr. Schmidt has omitted seem to be pertinent.

(1) Oil specifications are largely the result of efforts on the part of the purchasers of the oils to protect themselves from excessive prices, and of a tendency on the part of the producers to change their products without notice.

(2) Many companies have effected important savings of time and money by the use of specifications, although probably none of the specifications was perfect.

(3) Conditions of the consumers' specifications can hardly be more chaotic than the recommendations of different oil companies.

We agree with Dr. Schmidt as to the desirability of having oil specifications cover the important properties, which should be determined from the standpoint of use rather than the ease of making tests in the laboratory or from any peculiar property that an oil from a certain geographical source may possess.

Oils Numbered Only by Viscosity

The S.A.E. Lubricants Division has been working on motor-oil specifications for a number of years. At first it formulated specifications with wide limits somewhat in accord with Dr. Schmidt's suggestions, but these specifications were not favored by the oil companies. It was claimed that the limits were too wide and that no reputable oil company would permit its oils to be classified under a specification which would also cover other oils with different flash-points, Conradson carbon, color, and so on. However, when the S.A.E. Lubricants Division attempted to write specifications with narrower limits, the oil companies objected more vigorously.

The next step was to omit all reference to such laboratory tests as flash, fire, color, Conradson carbon, and pour, and simply to define the viscosity limits covered by the terms light, medium, and heavy; but the oil companies could not agree to so simple a classification. For example, an oil of a certain viscosity might be classified by one company as medium and by still another company as heavy; one oil company might sell the same oil for a truck or tractor as "light," for a passenger car as "medium," and for a turbine as "heavy."

To overcome such difficulties, the S.A.E. Lubricants Division finally adopted the present system of Crankcase Lubricating-Oil Viscosity Numbers[4], which is outlined briefly in the S.A.E. HANDBOOK, p. 510.

What S.A.E. Numbers Accomplish

By the use of this system it will be possible for oil companies to mark their oils without loss of brand name, advertising prestige, or trademark good-will; and it should be possible for automobile companies to specify the viscosity of an oil desired for use in the cars they make, leaving such matters as flash-point, fire, Conradson carbon and the like to be mutually satisfactory to the buyer and seller. It should be emphasized that the S.A.E. Crankcase Lubricating-Oil Viscosity Numbers are a means of enabling the automobile owner to obtain oil of the proper viscosity.

To obtain competitive bids, large consumers of oil must describe the oil so that the suppliers will know what is wanted. The physical and chemical tests, crude as they may be, serve to describe the product to the supplier, and certainly bear a closer relationship to the use that is to be made of the product than the arbitrary trademark names which may be lithographed beautifully on the cans. Furthermore, many of the oils regularly marketed at present were developed as a result of attempts of the oil refiners to meet specifications which they regarded as weird and unreasonable but which, in reality, expressed only the consumers' desire for a product to meet new or different conditions.

Because of the facts as brought out in the report of Committee D-2 of the A.S.T.M. and in Mr. Mougey's discussion, the Society limited its oil specifications to the "most important single property of lubricating oil"; that is, viscosity. Since Mr. Mougey wrote his comments on the adoption of this specification, the system has met with increasing approval. Many oil companies that opposed the system at the start have fallen in line during the last year, and 75 oil companies are now listed by the Standards Department as using S.A.E. Viscosity Numbers on their products.

[3] M.S.A.E.—Chief chemist, General Motors Corp. Research Laboratories, Detroit; Vice-Chairman, Lubricants Division of the Society.

[4] See THE JOURNAL, April, 1926, p. 345.

Revising Materials-Testing Laboratories List

MANY requests from the public are received by the Bureau of Standards for tests which the Bureau cannot make because of the large amount of work it has to do for the Government.

The Department of Commerce and, of course, the Bureau of Standards endeavor to encourage the use of specifications for the purchase of commodities. It is believed that the most satisfactory results are obtained if the purchaser, from time to time, tests the commodities to determine whether they comply with the specifications. It is obvious that the Bureau of Standards cannot, in most cases, make these acceptance tests for the public. There is a growing demand for other laboratories which will render satisfactory service. The Bureau of Standards is glad to assist other materials-testing laboratories in rendering this important service.

On Jan. 21, 1926, the Bureau issued a Letter Circular entitled, Testing Laboratories Equipped for Mechanical Tests of Metals and Other Engineering Materials. This Letter Circular, listing commercial and technical-school laboratories, has been widely distributed to assist the public in selecting a laboratory having the necessary equipment. It is now being revised, and additions and corrections are solicited. The following items of information are requested:

(1) Name and address of laboratory, with list of branch laboratories if any
(2) Names and official titles of persons in responsible charge of work
(3) A complete list of testing machines, giving a description of any unusual equipment and the maximum size of specimen which can be tested
(4) Are commercial tests made?
(5) Kind of work preferred.

The S.A.E. has endeavored to keep in touch with college research work and to maintain a record of the personnel and equipment available. It therefore calls attention to this plea for the information necessary to compile such a list, and urges that persons in charge of the laboratories send the required data to the Bureau of Standards, Division VI, Section 5, Washington, D. C.

Production Engineering

Axle Gears and Housings[1]

Materials, Methods and Tolerances Used and Recommended by the Gleason Works

SPIRAL-BEVEL gears of the highest quality can be produced only when good design is combined with a good material and proper machining, cutting and heat-treating. When the gear cost is viewed without considering the rejection loss and the salvaging work incidental to faulty operation in the final assembly, the extra expense involved in the use of a good alloy-steel and fine machining is often the determining factor in adopting a cheaper material and method of manufacture. But the removal of a gear-set from its final assembly, reinspection and attempts at salvaging are very expensive items. In many cases, such costs far exceed the extra cost of finer materials and workmanship. Each operation should be viewed from the standpoint of how it will affect the final qualities of the product rather than from the standpoint of the specific cost of the particular operation. It may well be that a few cents expended judiciously in the first operations will save many times that amount later, by reducing rejections and reinspections.

The best type of gear forging is that made from a round-cornered square billet by the upsetting process. After being pierced and expanded into a ring, the blank is forged to the required shape. The advantage of such a forging is that the fibers of the metal are all parallel with the axis of the gear, which reduces the distortion and makes the gear of uniform strength. In the usual type of forging, the fibers are parallel but normal to the axis of the gear.

The general automotive practice today is to use S.A.E. 2315 nickel-molybdenum steel or its equivalent for gears, and either S.A.E. 2315 or S.A.E. 2512 for pinions that are to be case-hardened. In other cases, S.A.E. 3312 nickel-chromium steel is used with good results. Any steel selected should be readily machinable in the annealed state.

Machining the Blanks

The care used in the machining of gear and pinion blanks directly affects the quality of the finished gears. The methods should be determined with this fact in mind, so as to produce accurately sized and true-running blanks. The gear must be bored to size to fit the chucking plates snugly, and all the bores must be uniform; otherwise, arbors of varying diameters would be necessary. The use of a broach has proved very satisfactory for producing uniform-sized bores cheaply. The face and back angles should run true when the gear, mounted by the bore, is drawn up against the hub or shoulder. This is essential to permit truing up the hardened gear when grinding the bore and when testing after hardening to determine the accuracy of the cutting. The pinion blanks also must be true to size and without run-out. If the pinions are bored, the face and back angles and the shoulder must run true when the blank is mounted by the bore. If integral-type pinions are used, the bearing surfaces must run true with the face and back angles and with the shoulder against which the pinions are drawn up during the cutting and final mounting.

The following are suggested as practical tolerances for the machining of blanks:

	Plus	Minus
Outside Diameter, in.	0.000	0.005
Backing from Crown, in.	0.000	0.002
Bore, in.	0.001	0.000
Width of Face, in.	0.000	0.010
Back Angle, min.	15	15
Face Angle, min.	8	0

(Teeth not to be high at small end.)

Limits of run-out from mounting surface: back end of hub, 0.0005 in.; back angle, 0.002 in.; face angle, 0.002 in.

Gear and pinion blanks of case-hardening steel are often copper-plated by the cyanide process to a depth of about 0.002 in. to make possible further machine-work, such as drilling, splining and threading, after hardening. Web-type bevel-gears are also plated to prevent brittleness around the bolt or rivet holes. The plating is removed from the face and back angles before the teeth are cut. A sample of the steel from which the blanks are made should be tested to determine its machinability after hardening.

Cutting and Inspection

Cutting spiral-bevel gears is an extremely large subject, and only the points considered most important to obtain good results will be touched upon. These are: satisfactory machine and tool maintenance, good, substantial chucking-equipment, and a rigid soft-inspection.

Details of machine operation vary with the individual plant and the quality of its product. Any machine that is not producing good results should be turned over to the maintenance department for repair. The operator should have a knowledge of the correct operation of the machine and cutters since he, with the foreman, is directly responsible for the product in the soft state, and consequently in the hardened state. In mounting both gears and pinions for cutting, care should be taken to see that they run true on the machine. Any run-out or eccentricity in the cutting will invariably appear in the hardened gear or pinion and will, in many cases, be so noticeable that it will be difficult or impossible to salvage the part.

It is essential that the correct tools be used for both roughing and finishing, since any variation will introduce errors in the finished product.

Lastly, a rigid, 100-per cent inspection of the gears should be made to determine the accuracy of the tooth size, the tooth bearing and the distances of the mounting surfaces from the working surfaces of the gear.

All gears and pinions should be run after cutting to make certain the tooth bearing has been placed properly for the heat-treatment and that the cutter and machine operation are satisfactory. Some manufacturers make a practice of running all pinions for a short time with a hardened gear, to remove any roughness in the tooth surface resulting from the cutting. This operation is termed burnishing.

Heat-Treatment

Methods of heat-treatment are so varied that no attempt will be made to cover them in detail.

For gears, the Gleason practice is to carburize, cool in the pots, reheat, and quench in oil. In this last process the gears are quenched between dies bearing on the back and face angles, and the bore is held against shrinkage. After these operations, performed correctly with good steel, the gears should lie flat within 0.003 in. Gears properly hardened should not require straightening. The following are suggested as

[1] From a Cleveland Section Meeting paper by R. C. Wilson, of the Gleason Works, Rochester, N. Y.

practical limits after hardening and before grinding:

- The outside diameter should not run out more than 0.003 in.
- Bores should not be out of round more than 0.003 in., or be oversize more than 0.005 in.
- Ring gears should lie flat on a surface-plate within 0.003 in. at all points.
- The face angle should be held to a limit of minus 8 min., which means that the small end of the teeth should be high rather than low.

The same practice is followed on pinions as on gears, unless double heat-treatment is employed. In this case the pinions are dumped hot, quenched in oil, reheated, and quenched again. This method gives the best refinement of case and core, but requires a higher grade of steel to keep the distortion within practical limits.

After heat-treatment, integral-type pinions are straightened in a press. The run-out on the shank of the front bearing should not exceed 0.001 in.

Grinding Gears and Pinions

The backs of bevel-drive gears are ground in the soft state. It has been found unnecessary to regrind the backs in the hard state unless the web extension is too great or too thin, in which case the gear will have a tendency to dish in or out and grinding will be necessary to obtain the desired flatness.

In hard-grinding the webbed gears, the back is trued up with reference to the teeth or their equivalent, and to the back or face angle. When a hard grind is necessary, customary practice is to allow 0.003 in. for this operation. In any case, the bores are ground after hardening. The pinion bearings should be ground both before and after hardening. The soft size is generally made 0.010 in. larger than the final size, and the limits for both grinding operations are plus .0000 and minus 0.0005 in.

Gear Lapping

Lapping is a polishing operation to produce a smoothness that would otherwise come only after 500 miles of car operation. The accepted method of lapping provides for smoothing the entire working surface of the teeth. This is important, since a fixed tooth-bearing position cannot be maintained and some latitude must be provided because of the normal machining tolerances. Gears lapped and mounted in one fixed position will be satisfactory, however, if a selective system is adopted whereby the gears are lapped in exactly the same relative positions as they occupy in the carrier.

In production lapping, there are two essentials to provide closely uniform gears and pinions. These are control of cutting and control of heat-treatment. If only slight variation occurs, the tooth bearing of gears operated at correct mounting-distances will not extend to either end of the tooth, although it may shift slightly. Where the variations are large, the tooth bearing may become short and localized at the end of the teeth. This prevents rapid and economical production, as special settings and additional operations are required to transfer the tooth bearing to a suitable operating position in the final mounting. There must always be sufficient length of bearing to assure smooth, even operation without depending entirely on the profile contact for tooth overlap.

In the generally accepted production method of lapping, the gears are first mounted at the correct mounting distances and the tooth bearing observed. If a one-third to one-half-length bearing with a good profile is found, the gears are lapped in this position. Changes in gear-vertical and pinion-horizontal setting are then made to bring the tooth bearing to the toe on the drive side and the heel on the coast side, in which position also they are lapped. The settings are again changed to bring the bearing to the heel on the drive side and the toe on the coast side, and the lapping operation is continued. Lastly, the gears are lapped for a short time on a mounting distance increased 0.003 in. on the drive side and decreased 0.003 in. on the coast side. This last operation is to allow for deflection and incorrect setting in the axle.

After the lapping operation is completed, the gears should be checked for the best running-position, this mounting distance etched on the pinion, and the backlash is etched on the gear. The set should be assembled in the axle according to these figures.

Accuracy Required in Mountings

In machining the carrier for the differential and pinion bearings, the distance between the center lines of the gear and the pinion in a vertical plane should not be greater than 0.003 in., and the pinion should not be above. The pinion axis should be square with the gear axis within a limit of 0.005 in. in 12 in., and in no case should the shaft angle be less than 90 deg.

Following are believed to be safe limits for actual deflections: With full engine-torque in low gear applied to an axle, the pinion should not lift or depress more than 0.002 in. and should not yield axially more than 0.005 in.; and the bevel-drive gear should not lift or depress more than 0.002 in., or move away from the pinion at the meshing point more than 0.010 in.

Axle mountings must provide the rigidity necessary to assure that two-thirds of the theoretical working surfaces of the teeth shall be in action under any condition; otherwise, the true value of spiral-bevel gears is not realized. If too weak a mounting is provided, wear or breakage will often occur, because the heavy loads become concentrated on too small an area of the teeth. It is, therefore, of the greatest importance to maintain correct alignment between the gear and pinion at all times. It is obvious that, unless two engaging teeth mesh with the proper tooth-bearing, their ability to transmit load is lessened, the overlapping action of the spiral-bevel gear is not obtained, and noisy gears are the natural result.

Foreman Conferences

THERE is a growing appreciation of the fact that the value of an organization is not determined by the inventory value of the land, buildings and equipment, but by its "productive capacity"—its ability to do things. One of the most important elements in the productive capacity of an organization is its supervisory force.

The foremen are the points of contact between the men and the management. They are responsible in the final analysis for the carrying out of the policies of the management, and their success in doing this has a profound effect on the worker and on the public. The management may have a broad, generous attitude toward its employes and a liberal policy toward its customers, but all of this can be nullified absolutely by the stubbornness of a narrow-minded foreman.

One valuable result obtained through foreman conferences is the training and experience given in analysis. Participation in the discussion of the various topics forces the men to study their jobs from all angles. It breaks them of the bad habit of "jumping at conclusions" without having all the facts in the case on which to base their conclusion. They are brought to a realization of the fact that there are always at least two sides to every story, and that a study of both is essential in making an intelligent decision.

The foreman conference is one of the best methods that we have discovered for getting accident-prevention work started on a sound basis. It not only gives the foremen an opportunity to become acquainted with the problem, but trains them to study and analyze it without fear or prejudice. It has concentrated their attention on the great importance of the three factors in good foremanship—selection, training and supervision. The intelligent application of these are basic in accident prevention, as well as in any other phase of operation.—Herbert B. Flowers, president, New Orleans Public Service, Inc., in *Executive Service Bulletin.*

Transportation Engineering

Cost-Accounting System

Discussion on L. V. Newton's Subcommittee Report Presented at the Transportation Meeting

FOLLOWING is the discussion at the Transportation Meeting in Newark, N. J., in October, 1928, on the report of Subcommittee No. 7 of the Operation and Maintenance Committee (now the Transportation Committee). The report, prepared by L. V. Newton, of H. M. Byllesby & Co., and read at the meeting by Chairman R. E. Plimpton, of the main Committee, was published in the December issue of the S.A.E. JOURNAL, p. 625.

THE DISCUSSION

COKER F. CLARKSON[1]:—Uniform cost-accounting is obviously difficult; it is a complicated subject but, on a theoretical basis, at least, it is vitally important. We have had various cost systems in effect, but only one has ever been used to any great extent, although it is not used widely now. The fundamentals or broad divisions of expenses, as shown in Mr. Newton's classification, are common practice. We have received statements of the method used by many large operating organizations. There is not a great variety in the steps in their practices, but it is clear that it is difficult to devise any system that might be decided on as good enough to get it actually reduced to practice. The reason is largely that two public accountants will very quickly disagree on some of the points of the methods of keeping accounts.

There are two schools of accountants, those of the old school for general business accounting and those of the more modern school who deal with accounting of the engineering type. For example, they differ on how to figure interest. Those of the old school would say, "Do not charge interest on your investment." But the engineering idea is that one should do so, whether at a constant rate or at a reducing rate proportionate to the depreciation of the equipment, or on an average rate of depreciation that it is thought will cover the life of the equipment. There are various differences of views as to how to figure depreciation, what is included under the term "overhead," and other difficulties.

The practical side is that, however important uniform cost-accounting is, and however much good it can do, the whole scheme can never amount to very much unless sufficient cooperation of the larger organizations involved can be aroused to settle first on a standard cost-determining system that they consider sufficiently good, get them to reduce it to practice in their own service stations, and then accumulate data. It will take time to devise a system, more time to get it reduced to practice, and some years under conditions of making the best progress possible before we shall actually have comparable data such that, in determining costs, one man can judge whether at a given time he is doing better or worse than he was before, or better or worse than another man who is working along parallel lines.

Closer Agreement of Set-Ups Desired

CHAIRMAN R. E. PLIMPTON[2]:—Some of these accounts were broken up; for instance, as defined by Mr. Newton, account No. 18 included elements that, under the American Electric Railway Association classification, could have been separated under the maintenance and transportation group. The same difficulty appeared under account No. 20. I think it would be a very good thing if we could have any accounts that we recommend defined in such a way that they will be comparable with the simple A. E. R. A. classification. To get some expert information, I wrote to E. A. Tuson, general auditor of the Public Service Coordinated Transport, in Newark, and chairman of a standing committee of the American Electric Railway Accountants' Association that keeps this classification up to date. His reply says:

> In the interests of standardization, I am submitting a few comments. There is a little to be said in criticism of Mr. Newton's suggested plan as a cost-account system. It is well thought out, logical, and provides for all factors of cost. From the viewpoint of standardization, however, and in consideration of the fact that many motorcoach owners operate trucks, I submit herewith a tabular comparison of Mr. Newton's set-up with the operating-expense accounts provided for in the Standard Classification of Accounts for motorcoach operators having an annual operating revenue of less than $100,000. Whatever can be done to bring these two accounting set-ups into closer agreement as to arrangement should be done for the sake of the operators of automotive-transportation equipment. It is recognized that some minor differences of treatment are necessary where transportation is but incidental to a manufacturing industry.

Basis of A.E.R.A. Classification

M. F. STEINBERGER[3]:—Why are oil and gasoline called an operating-garage expense in the Standard Classification? Why are they not transportation expenses?

C. ROGGE[4]:—Considerable discussion transpired at the 1925 meeting of the A. E. R. A. as to how the accounts should be grouped. It was decided that they should be divided into the five operating groups shown in the Standard Classification. Maintenance and operating-garage expenses, Classes I and II, differentiate between those costs which would actually occur in direct maintenance and those which are more or less applicable to both groups. In Class I, we start with superintendence of transportation, follow it with maintenance-department expense such as rents and upkeep, and then consider the maintenance of vehicles. We then come to Class II, which includes gasoline, oil, garage employees and garage expenses. It is evident that Class II is not involved in direct maintenance.

CHAIRMAN PLIMPTON:—Class II is just a compromise. Some say that it should be included in Class I, and others favor its inclusion in Class III; therefore, it is made a separate group and can be added to either Class I or Class III.

Where Depreciation Belongs

A. J. SCAIFE[5]:—Is the Standard Classification used by the electric railways only?

CHAIRMAN PLIMPTON:—It is the classification adopted by the American Electric Railway Accountants' Association and substantially adopted by the National Association of Utility and Railroad Commissioners.

MR. SCAIFE:—Depreciation, for instance, is classed under maintenance,

[1] M.S.A.E.—Secretary and general manager, Society of Automotive Engineers, New York City.

[2] M.S.A.E.—Associate editor, *Bus Transportation*, Chicago.

[3] M.S.A.E.—Manager highway transportation, Baltimore & Ohio Railroad, Baltimore.

[4] Assistant to general auditor. Public Service Coordinated Transport, Newark, N. J.

[5] M.S.A.E.—Consulting field engineer, White Motor Co., Cleveland.

and that is not always done. How should it be classed?

MR. ROGGE:—I understand that an effort is being made now by the committee of which Mr. Tuson is chairman, to provide a separate group for what, in the A. E. R. A. classification, is called "retirement expense." There has been considerable discussion as to whether depreciation properly belongs under maintenance general miscellaneous expenses. We have, of course, many adherents in either group. I think that will be another cause for compromise in the establishment of a separate group to cover just retirement expense, the same as was done with the operating-garage group as regards both the transportation and the maintenance groups.

Interstate Coach-Operation Accounting

MR. STEINBERGER:—We all know that for the last three or four years efforts have been made to get legislation through the Senate and the House of Representatives looking toward some control of interstate motorcoach-operations. If that is done, such companies probably will be required to submit accounts, reports and statistical information that is not now available. It is natural that if this material is turned over to the Interstate Commerce Commission and the Commission sets up the accounts, it will use railroad accounting as the basis, as it is familiar with that. Railroad accounting provides for such items as I mentioned, and if it is the intention to go into transportation accounting, I wonder whether the Society ought to recommend a system of accounts that may possibly be at variance with some other system used by the Interstate Commerce Commission.

CHAIRMAN PLIMPTON:—The reason for presenting it in this form is that it is believed the great majority of motor-vehicle operators would not require consideration of a regulatory situation. They are mostly private operators who are not under control and are not likely to be. We are recognizing the other group, the public-service companies, to the extent of trying to make the accounts comparable. An unfortunate difference is reflected in the recent classification adopted in Pennsylvania. The Interstate Commerce Commission and the American Electric Railway Association accounting-systems class depreciation under maintenance, whereas the Pennsylvania Public Service Commission, evidently in its desire to follow the same practice adopted for electric and gas public utilities, puts depreciation elsewhere under operating expenses.

Points Basis for Prorating to Units

L. V. NEWTON[*]:—I do not favor the suggestion of setting up the various items of motor-vehicle operating expense in the same form as that of the American Electric Railway Association, as I do not believe that anything is to be gained by so doing.

The plan suggested of segregating variable expense and fixed expense has one great advantage; that is, regardless of how operators may treat their fixed expense, it is likely that they will treat variable expense in comparable manner so that one operator can compare his variable or operating expenses on similar vehicles with those of another operator.

The question has been raised of the basis on which items such as overhead, rent and storage are charged to each vehicle. I suggest that indirect Garage Expense, Rent and Storage, and General Expense be prorated over each vehicle involved on a point basis, as follows:

PASSENGER-CARS

Original Cost	Points
\$400 to \$700	5
701 to 1,100	8
1,101 to 2,000	10
over 2,000	20

MOTOR-TRUCKS

Capacity, Tons	Points
½	5
¾	8
1 to 1½	10
2 to 2½ and 3	20
3½ and up	25
Motorcycles	5
Trailers	2
Electric trucks, all capacities	10
Tractors, all capacities	10

Shop-overhead charges should be prorated over each job in accordance with the productive-labor hours expended on each job.

As for comments regarding depreciation, I do not agree to classifying this charge under maintenance. Rather do I believe it should be treated as a fixed charge, as recommended.

I urge the Committee handling cost accounting to treat the subject independently of motorcoach accounting. The system as recommended gives the small as well as the large truck operator the data and facts he requires to handle his truck operation intelligently. And, as stated by Mr. Tuson, it provides for all factors of cost.

[*] M.S.A.E.—Automotive engineer, H. M. Byllesby & Co., Chicago.

STANDARD CLASSIFICATION	NEWTON'S COST-ACCOUNTING SYSTEM
I. Maintenance of Plant and Equipment	
Superintendence of plant and equipment	(18) Superintendence (part) (20) Overhead expense (part)
Maintenance of buildings and shop equipment	(14) Garage rent and maintenance (20) Overhead expense (part)
Maintenance of vehicles	(4) Repair material used on chassis (5) Repair material used on cab, body or auxiliary equipment (6) Repair labor used on chassis (7) Repair labor used on cab, body or auxiliary equipment (8) Painting labor and material (9) Accident labor and material
Tires and tubes	(3) Tires and tire repairs
Retirement expense	(17) Depreciation on vehicles
II. Operating-Garage Expenses	
Fuel	(1) Gasoline and electric energy
Lubricants	(2) Oil
Garage employees	(10) Garage labor (20) Overhead expense (part)
Garage supplies and expenses	(11) Garage material (12) Miscellaneous expense (20) Overhead expense (part)
III. Transportation	
Superintendence of transportation	(18) Superintendence (part) (20) Overhead expense (part)
Operators	(13) Chauffeurs' and helpers' wages
Station expenses	None
Other transportation expenses	(12) Miscellaneous expense (part)
IV. Traffic Promotion	
Traffic expenses such as advertising	None
V. Administrative and General Expenses	
General officers, salaries and expenses	(21) Administrative expense (part)
Other general-office salaries and expenses	(21) Administrative expense (part)
Liability and other insurance	(15) Insurance for vehicles
Other general expenses	(20) Overhead expense (part)
Taxes	(16) Licenses and taxes on vehicles
Income deductions	(19) Interest on investment in vehicles

Standardization Activities

Automobile Bumper-Mounting

Subdivision To Recommend Revision of Heights and Method of Measuring

THE trend to lower passenger-cars necessitates consideration of the present S.A.E. Specifications on Passenger - Car Bumpers, p. 213 of the 1929 edition of the S.A.E. HANDBOOK, with particular reference to height from the ground. For this purpose the Subdivision on Passenger - Car Bumpers met in Detroit on March 25 to formulate a revision to be recommended.

The proposed height at which both front and rear bumpers should be set must be determined, for the purpose of fixing the standard, at some definite loading of the car. In the past, the specification has called for this measurement to be taken with the car empty except for the normal load of water, oil and gasoline. It was determined that in general use cars carried an average load which could be approximately determined for each type of passenger-car. It was also determined by the Subdivision that, because there is an approximately constant spring-deflection as the load increases, the average load would bring the frame half way between its position at no load and at full load. Therefore the Subdivision recommends that the following paragraph be substituted for paragraph 6 of the present specification as the third paragraph, immediately following the paragraph specifying the bumper height:

The bumper heights specified shall be the mean determined from no-load and full-load position with the car carrying the full amount of gasoline, oil and water.

Recommended Heights and Tolerances

It is also recommended that the bumper heights as given in paragraph 2 of the present specification be revised as follows:

The horizontal center-line of the bumper face, exclusive of fittings, shall be 17 in. plus or minus ⅛ in. per inch of effective face above the ground for front bumpers, and 17 in. plus or minus ¼ in. per inch of effective face above the ground for rear bumpers or fender guards.

Since the bumper-height tolerances depend upon the width of face of the bumper, it was thought necessary to define the position on the bumper where the bumper face is to be measured, particularly in view of the many designs using curved bars, which provide considerable width at the center of the bumper but not elsewhere. The Subdivision therefore proposes to revise paragraph 7 of the present specifications to read:

The vertical spread of contact face of bumper assemblies is the distance between the upper and lower edges of the bumper impact-bar or bars, and shall be measured at the extreme outer end thereof.

Addition to Mounting Specification

Heretofore the bumper - mounting specifications have made no provision to assure that the bumper face shall be set at the correct angle to the horizontal. It is thought that such an addition to the specification is advisable to enable manufacturers who provide integral spring-horn mountings or similar brackets to make the face of pads in such a way that the bumper, when mounted, shall have its face at the correct angle and not detract from the appearance of the car. The Subdivision recommends the addition of the following specifications:

The faces of the mounting pads for the front bumper shall be perpendicular to the ground when the car is unloaded.

The faces of the mounting pads for the rear bumper shall be perpendicular to the ground with the car fully loaded.

Some consideration was given to the desirability of eliminating the present Front-Bumper-Mounting Recommended Practice, p. 213 of the 1929 edition of the S.A.E. HANDBOOK, as almost all cars are being provided with an integral or standard spring-horn mounting-bracket. It was believed desirable, however, to retain this specification until the few cars now using the former method of attaching bumpers should change; but the Subdivision recommends that a paragraph be inserted under the title to read:

This method of bumper mounting is intended for use only where bumpers are mounted by means of a bracket secured against the web of the frame side-member.

The foregoing Subdivision recommendations will be presented to the Parts and Fittings Division and the Standards Committee for approval.

Steel Specifications

Three New Steels Approved and Minor Revisions in Existing Specifications Recommended

REPORTS on various subjects now in progress were discussed at a meeting of the Iron and Steel Division in Detroit on March 28. A progress report on the work being done by the Subdivision on Heat-Treatment Notes, involving complete revision of the existing Notes in the 1929 HANDBOOK, was submitted by R. B. Schenck, chairman. It was decided that, to produce the best results, the Division should entirely rewrite all of the Heat-Treatment Notes rather than attempt to revise the present ones.

The Division was advised that work on the test of No. 3130 steel, to be conducted for the purpose of checking the efficiency of the probability method of determining physical-property charts, is progressing rapidly. The steel furnished by the five steel companies has been cut up and was about to be sent to the various cooperating laboratories.

While there has been considerable agitation for the Division to consider publishing in the HANDBOOK some information or data on stainless steels, it was the consensus of opinion that, because of the proprietary nature of such steel, it would be impracticable for the Standards Committee, under its present regulations, to attempt such action.

Two Steel Substitutions Proposed

Discussion was held on the advisability of substituting one steel to be known as S.A.E. Steel No. 1355, having a carbon content of 0.50 to 0.60, for the two S.A.E. Steels Nos. 1350 and 1360. Considerable difference of opinion was expressed as to the desirability of such a substitution, and the Standards Department was requested to circularize steel makers and users regarding this proposed action. Similar action was taken relative to a like proposal to substitute a proposed No. 9255 steel in place of S.A.E. Steels Nos. 9250 and 9260.

The Standards Department has also been requested to circularize the interested trade to determine whether a steel to be known as S.A.E. No. 2325 and having a chemical composition similar to S.A.E. No. 3125 and 6125 should be designated.

Likewise, the industry will be circularized to ascertain whether sufficient usage is made of the high-speed tungsten steels now shown in the HANDBOOK under the Nos. 71360, 71660 and 7260 to justify their continuance or action should be taken by the Division looking toward their cancellation.

Some criticism has been received by the Division that the present S.A.E. Specifications for screw stock differs from the compositions of screw stock being manufactured and used in large quantities. So that this subject might be given thorough consideration, it was decided to authorize the Chairman to appoint a subcommittee of three to work with a similar committee from the American Society for Testing Materials to formulate specifications on types of screw stock and revise the present S.A.E. Screw-Stock Specifications if necessary. This subcommittee's report will be taken up at the next Division meeting.

New Steels Nos. 3145 and 3150

At present there are no S.A.E. Steels Nos. 3145 and 3150, whereas steels having these two carbon-ranges are included in the 2300 series, the 3200 series and the 60,100 series. Since considerable tonnage of such steels is used at present, approval of the following two steels will be recommended to the Standards Committee in June:

Proposed S.A.E. Steel 3145 will have the following chemical composition: carbon range, 0.40—0.50; manganese range, 0.30—0.60; phosphorus maximum, 0.04; sulphur maximum, 0.045; nickel range, 1.50—2.00, and chromium range, 0.90—1.25.

Proposed S.A.E. Steel 3150 will have the following chemical composition: carbon range, 0.45—0.55; manganese range, 0.30—0.60; phosphorus maximum, 0.04; sulphur maximum, 0.045; nickel range, 1.50—2.00; chromium range, 0.90—1.25.

New Steel No. 6115

At a previous Division meeting consideration was given to recommending the addition of a new chromium-vanadium steel to be known as S.A.E. 6115. Through an error this was never submitted to the Standards Committee, and at the March 28 meeting the Division reaffirmed its previous stand and recommended that this steel be submitted to the Standards Committee in June for addition to the present steel specifications. The chemical composition proposed is: carbon range, 0.10—0.20; manganese range, 0.30—0.60; phosphorus maximum, 0.04; sulphur maximum, 0.045; chromium range, 0.80—1.10; vanadium minimum, 0.15; vanadium desired, 0.18.

Revised Sulphur Content

The previous action of the Division in recommending the increase of sulphur in all S.A.E. Steels by 0.005 was approved, and the specifications as appearing in the 1929 edition of the HANDBOOK show this change on all types of steel. After further discussion at the March meeting it was the consensus of opinion of the Division that the increase in sulphur content should not have been made to apply to Steels 1095, 1350, 1360, X-1315, 1112 and 1120. It was therefore voted to reduce the sulphur content on these steels by 0.005 and to submit this change to the Standards Committee in June for approval. If approved, this will revise the sulphur content on Steels 1095, 1350 and 1360 from 0.055 to 0.050, and on Steels X-1350 from 0.085—0.135 to 0.080—0.130, and on Steels 1112 and 1120 from 0.08—0.155 to 0.075—0.15.

No. 4100 Steels Revised

At the time the original suggestion for a new Steel No. 6115 was made, it was also proposed to revise the manganese content of S.A.E. Steels 4130, 4140 and 4150 from 0.40—0.70 to read 0.50—0.80, but no action has been taken on this by the Standards Committee. The Division therefore also reaffirmed its stand on this change, which will be submitted for approval in June.

Silicon Content of Steels

The question of adding silicon specifications to alloy steels was discussed and it was decided that on all S.A.E. basic open-hearth alloy steels the silicon content should be specified as 0.15—0.30 and a note added to the specifications that on electric and acid open-hearth S.A.E. Steels the minimum silicon should be 0.15, with no high limit shown. This proposed revision of the alloy steels will also be submitted to the Standards Committee for approval at its next meeting.

Using Viscosity Numbers

Ninety-nine Refineries and Oil Companies Employing S.A.E. System on Labels and Charts

ADOPTION of the S.A.E. Viscosity Numbers as a means of designating the viscosity of lubricating oils for automotive use has been widespread. During the last 18 months, 99 refiners and oil companies have advised the Society that they are using these numbers in conjunction with their brand names as an additional means of designating the viscosity of the oils supplied in their containers. Many of these refiners have incorporated the numbers in their lubrication charts, both separately from their brand names and in conjunction with them.

Automobile manufacturers whose output constitutes the majority of the cars made in this Country, and also several industrial-engine and tractor manufacturers, are using the S.A.E. Viscosity Numbers as a means for recommending suitable grades of oil for their engines.

The attached list gives the names of the companies that have to date adopted this system.

Oil Companies Using S.A.E. Viscosity Numbers

American Oil Co., Baltimore
American Oil Corp., Jackson, Mich.
American Oil Works Co., Titusville, Pa.
American Refining Properties, Wichita Falls, Texas
Anglo-Mexican Petroleum Co., Ltd., South America
W. H. Barber Co., Chicago and Minneapolis
Barnsdall Refineries, Inc., Tulsa, Okla.
Barstone Oil Co., Chippewa Falls, Wis.
Beacon Oil Co., Everett (Boston), Mass.
British American Oil Co., Ltd., Toronto, Canada
Burger-Adams Petroleum Co., Coffeyville, Kan.
Champlin Refining Co., Enid, Okla.
Cincinnati Oil Works Co., Cincinnati
Cities Service Oil Co., New York City
Cities Service Oil Co., Cleveland
Cities Service Refining Co., Boston
Fred G. Clark Co., Chicago
Crew Levick Co., Philadelphia
Dearborn Chemical Co., Chicago
Deepwater Oil Refineries, Inc., Houston, Texas
Henry L. Doherty & Co., New York City
Eason Oil Co., Enid, Okla.
Economy Oil Co., Salina, Kan.
Empire Oil & Refining Co., Tulsa, Okla.
Emery Mfg. Co., Bradford, Pa.
Freedom Oil Works Co., Freedom, Pa.
Gay Oil Co., Little Rock, Ark.
Griffith-Consumers Co., Washington, D. C.
Gulf Refining Co., Pittsburgh
Hartol Refining Corp., New York City
Henderson Oil Co., Winnipeg, Canada
Illinois Oil Co., Rock Island, Ill.
Imperial Oils, Ltd., Toronto, Canada
Independent Oil Men of America, Chicago
Independent Lubricating Co., Inc., Topeka, Kan.
Interstate Oil Co., La Crosse, Wis.
Indian Refining Co., Lawrenceville, Ill.
Inter-State Oil Co., Inc., Minneapolis
Jayhawk Oil Co., Inc., Salina, Kan.
Jenkin-Guerin Oil Co., St. Louis
Kendall Refining Co., Bradford, Pa.
Knight Oil Corp., New York City
Lincoln Oil Refining Co., Robinson, Ill.
Litwood Oil & Supply Co., Fort Worth, Texas
C. H. Lockwood Oil Co., Kenosha, Wis.

Louisiana Oil Refining Corp., Shreveport, La.
Lubrite Refining Co., St. Louis
Magnolia Petroleum Co., Dallas, Tex.
Marland Refining Co., Ponca City, Okla.
Master Petroleum Co., Waco, Texas
Cia. Mexicana de Petroleo El Aguila S. A., Mexico City, Mexico
Mexican Petroleum Corp. of Maine, New York City
Mid-Continent Petroleum Corp., Tulsa, Okla.
New York Lubricating Oil Co., New York City
Nourse Oil Co., Kansas City, Mo.
Osborne Oil Co., Rockford, Ill.
Pan-American Petroleum & Transport Co., New York City
Pan-American Petroleum Corp., New Orleans
Pan-American Petroleum Corp. of Tennessee, Memphis
Panhandle Refining Co., Wichita Falls, Texas
Pennsylvania Consumers Oil Co., Council Bluffs, Iowa
Pennsylvania Petroleum Co., North Kansas City, Mo.
Pennzoil Oil Co., Oil City, Pa.
Pierce Petroleum Corp., St. Louis
Plains Lubricating Co., Inc., Amarillo, Texas
Quaker Petroleum Co., Omaha
Red Hat Oil Corp. of Texas, Fort Worth
Refiners Oil Co., Dayton, Ohio
Richfield Oil Co. of California, Los Angeles
Rosier Oil Co., Hutchinson, Kan.
Rush Oil Co., Philadelphia
Satin Oil Corp., Tulsa, Okla.
Schock Independent Oil Co., Mount Joy, Pa.
Shaffer Oil & Refining Co., Chicago
Sherwood Bros., Inc., Baltimore
Sinclair Refining Co., New York City
Standardized Lubricants Co., Tulsa, Okla.
Standard Oil Co. of California, Richmond, Calif.
Standard Oil Co., Cleveland
Standard Oil Co. (Indiana), Chicago
Standard Oil Co. of New Jersey, Newark
Standard Oil Co. of New York, New York City
D. A. Stuart & Co., Chicago
Sun Oil Co., Philadelphia
Texas Co., New York City
Texas Pacific Coal & Oil Co., Fort Worth, Texas
Tide Water Oil Co., New York City
Tiona Refining Co., Philadelphia
Top Grades Oil Co., Fort Worth, Texes
Transcontinental Oil Co., Tulsa, Okla.
United Oil Mfg. Co., Erie, Pa.
Vacuum Oil Co., New York City
Valvoline Oil Co., Chicago
Wadhams Oil Co., Milwaukee
Ward Oil Co., Inc., North Tarrytown, N. Y.
White Eagle Oil & Refining Co., Kansas City, Mo.
White Star Refining Co., Detroit
Willhelm Oil Co., St. Paul
Winona Oil Co., Winona, Minn.

Slotted-Head Screw Standard

PROPOSED standardization of the proportions of slotted-head screws, including wood screws, was presented in full in the September, 1928, issue of THE JOURNAL beginning on p. 322. At that time the report was submitted for final comment by industry in general before it was submitted for final approval by the sponsors for the Sectional Committee formulating it and by the American Standards Association, under the procedure of which the work has been done.

The Sectional Committee on the Standardization of Bolt, Nut and Rivet Proportions, which is responsible for the report, is sponsored by the Society and the American Society of Mechanical Engineers. Since the report was printed last September, a few minor changes have been made by the Sectional Committee, such as rearranging the reference numbers for the definitions of types of head to correspond with the table numbers for the dimensions of similar heads. Other changes worth noting are clarified wording of the note printed under Tables 1 to 4 for machine screws and under Tables 6 to 8 giving the dimensions of cap screws. The illustrations for Tables 2 and 7 have been improved. In the specification for the points of cap screws, given on p. 326 of the September issue of THE JOURNAL, "—5 deg." was a typographical error and has been corrected to read "+5 deg." In the caption of Table No. 13, the words "Maximum and Minimum" have been deleted.

Division to Act Soon

The Society, in approving Sectional Committee reports for adoption as American Standards, follows the same procedure as in the adoption of S.A.E. Standards and Recommended Practices. This report has accordingly been referred to the Parts and Fittings Division of the Standards Committee for review and recommendation at the Standards Committee meeting to be held during the Semi-Annual Meeting at Saranac in June. The formulation of the report has required a large amount of time and work of the Sectional Committee and any criticisms of the report submitted should be constructive and of real importance. Such criticisms should be sent to the Society's Standards Department promptly so that they can be submitted to the Parts and Fittings Division or the Standards Committee. It is expected that the Parts and Fittings Division will take definite action on the report at a meeting to be held on May 8.

Standards Ballots Discontinued

Council of the Society Approves Reduction of Time Required for Adoption of Standards

QUICKER procedure in the final adoption of Standards by the Society will, it is believed, be effected by the action taken by the Council of the Society at its April 9 meeting whereby recommendations for adoption will be ordered to publication in the S.A.E. HANDBOOK or as otherwise provided, at the Annual and Semi-Annual Business Session of the Society. This eliminates the final letter-ballot heretofore required by the Standards Committee Regulations.

Analysis of a careful record of the results of all standards letter-ballots taken since March, 1918, indicates that at no time in that period has a standard been rejected by a ballot on final adoption. The average number of ballots returned by members during that period equals about 10.5 per cent of those sent out, the highest return being 19.7 per cent and the lowest 6.1 per cent. The average number of negative votes on a given subject has not exceeded 1 per cent of the number of ballots cast, or approximately 0.1 per cent of the number of ballots sent to the members.

The greatest advantage resulting from the change will be that the annual edition of the S.A.E. HANDBOOK, or the semi-annual Supplement thereto, can be sent to the members approximately four weeks earlier than heretofore when the letter-ballot was required.

The practice of publishing all Standards Committee recommendations in the S.A.E. JOURNAL and circulating them widely by mail will be continued so that all members of the Society and others who are interested will have ample opportunity to review proposed standards and have a voice in their formulation before they are finally approved at the Annual and Semi-Annual Meetings.

The present regulations of the Standards Committee, Article V, paragraphs (t) to (w) inclusive, printed on p. 573 of the 1929 issue of the S.A.E. HANDBOOK, will be revised to conform to the more expeditious procedure approved by the Council.

Aeronautic Engineering

New Aeronautic Standards

Aircraft and Aircraft-Engine Divisions Approve New Standards and Revisions After General Conference

THE morning of the second day of the Aeronautic Meeting in Detroit, Wednesday, April 10, was devoted to a general conference on standardization and to meetings of the Aircraft and Aircraft-Engine Divisions. It was the original intention to present before one general conference reports on all of the subjects under consideration by each of the Divisions and to ask each Division to take action on them at the close of the conference. However, because of the time required to adequately consider the Aircraft Division's reports on airplane tires, wheels, rims and axle-ends, it was found necessary to split the general conference into two parts, one to consider the Aircraft Division reports while the other section adjourned to another room to discuss the Aircraft-Engine Division subjects.

Tires, Wheels, Rims and Axles

The report presented by Chairman B. J. Lemon, of the Subdivision on Airplane Tires, Wheels and Rims, was divided into its various phases and the discussion was very detailed, particularly with reference to tire sizes and axle ends and the use of antifriction bearings. The final report, as submitted to the Aircraft Division meeting which followed immediately, is comprised of the following tables and illustrations, which constitute the report of the Subdivision. The report was approved in its entirety as a series of S.A.E. Recommended Practices, because of the probability of revisions from time to time. Each of the several subjects is to be submitted to the Standards Committee in June.

Instrument Mountings and Case Dimensions

The Subdivision that has been working for the last 12 months developed and circulated to the industry for comments two specifications providing over-all case-dimensions and mounting-dimensions for the 1⅞-in. and the 2¾-in. cases. These specifications, which are in accord with the instrument-case

AIRPLANE-TIRE DIMENSIONS

(*Proposed S.A.E. Recommended Practice*)

Wheel Size	Rim Dimensions: Width Between Flanges	Rim Dimensions: Ledge Diameter	Standard Tire Size	Oversize Tire for Extra Cushioning	Actual Tire Dimensions, Plain Tread: Tire Section Width Min.	Tire Section Width Max.	Tire Over-all Height Min.	Tire Over-all Height Max.
10x3	2⅛	4	10x3		3.12	3.18	10.24	10.36
14x3	2⅛ DC	8	14x3		3.12	3.18	14.24	14.36
				16x4	3.96	4.04	15.90	16.06
18x3	2⅛ DC	12	18x3		3.12	3.18	18.24	18.36
				20x4	3.96	4.04	19.90	20.06
24x4	2½ DC	16	24x4		3.96	4.04	23.90	24.06
				26x5	4.83	4.93	25.56	25.76
28x4	2½ DC	20	28x4		3.96	4.04	27.90	28.06
				30x5	4.83	4.93	29.54	29.74
30x5	3 DC	20	30x5		5.00	5.10	29.56	29.76
				32x6	5.83	5.95	31.31	31.53
32x6	4 DC	20	32x6		6.17	6.29	31.33	31.55
				36x8	7.78	7.94	34.88	35.18
36x8	5 DC	20	36x8		8.12	8.28	34.91	35.21
				40x10	9.74	9.95	37.99	38.35
44x10	6 DC	24	44x10		10.07	10.28	42.04	42.40
54x12	7 DC	30	54x12		12.00	12.26	51.63	52.07
				58x14	14.22	14.50	55.26	55.78

LOADS AND INFLATION OF AIRPLANE TIRES

(*Proposed S.A.E. Recommended Practice*)

Air Pressures, Lb. per Sq. In.

Tire Size	30	35	40	45	50	55	60	65	70
	Loads, Lb.								
10x3	195	230	260	290	325				
14x3	240	280	320	360	400				
18x3	315	370	420	470	525				
16x4	360	420	480	540	600				
20x4	465	540	620	700	775				
24x4	510	595	680	765	850				
28x4	600	700	800	900	1,000				
26x5	810	945	1,080	1,215	1,350				
30x5	950	1,120	1,280	1,440	1,600				
32x6		1,400	1,600	1,800	2,000	2,200			
36x8		2,330	2,670	3,000	3,330	3,670	4,000		
40x10			3,390	3,810	4,230	4,650	5,080	5,500	
44x10				4,360	4,850	5,330	5,820	6,300	
54x12				6,430	7,150	7,850	8,570	9,280	10,000
58x14				9,650	10,700	11,800	12,850	13,900	15,000

AIRPLANE-TIRE VALVES

(*Proposed S.A.E. Recommended Practice*)

AIRPLANE TIRE VALVES[1]

Valve	Tube
Tire and Rim Association No. 43	10x3
Tire and Rim Association No. 61	14x3
	18x3
	16x4
	20x4
Tire and Rim Association No. 62	24x4
	26x5
	28x4
Tire and Rim Association No. 63[a]	30x5
	32x6
	36x8
	40x10
Tire and Rim Association No. 44	44x10
	54x12
	58x14

[1] When this table is submitted to the Standards Committee it will be accompanied by drawings of the five types of valve mentioned, and if the recommendation is approved the table and drawings will be published together as an S.A.E. specification.

[a] No. 63 valve may have 10 deg. maximum stem-tilt in 8-in. rim.

specifications recently approved by the Army and Navy Standards Conference, provide cases in which all known instruments will fit. The type and location of attachments or drives are to be made the subject of further study by the Subdivision, and it is expected that this study will result, for each type of instrument, in individual specifications showing, besides the case dimensions and mounting dimensions given herewith, the location and method of attachment of drives or other connections. The specifications, as they will be submitted to the Standards Committee for approval in June, were printed in the April issue of THE JOURNAL on p. 445, no change having been made except the correction of the radius of the mounting lug from 3.16 in. to 7/32 in. on the illustration of the 1⅞-in. case.

AERONAUTIC STORAGE BATTERIES

(Proposed Revision)

Since the adoption of the original specification on aircraft storage batteries on pp. 13 and 14 of the 1929 edition of the HANDBOOK, the Subdivision has ascertained that the 20-min. rating, as approved, differs somewhat from the rating actually obtained in commercial production. Therefore the Division submits to the Standards Committee the recommendation that these specifications be revised in the "Minimum Current for 20 Minutes" column to read as follows:

Battery Number	Minimum Current for 20 Minutes
32	44
34	66
36	99

In addition to the accompanying specifications, which were definitely formulated and acted on by the Aircraft Division, a report was submitted to the general conference by R. B. C. Noorduyn, of the Bellanca Aircraft Corp. of America, regarding the intent and purpose of the Standards Committee of the Aeronautical Chamber of Commerce, of which committee he is chairman. This Committee has been organized to correlate the ideas on standardization, as held by the various sections of the Aeronautical Chamber of Commerce, for transmission to the proper Standards Division of the Society.

With this in mind, Mr. Noorduyn suggested to the Society that the following subjects be given consideration; control pulley and pulley bearings; small-size splined propeller-hubs and shaft-ends; shock - absorber strut-ends; strut lengths.

The following subjects were suggested by H. A. Hicks, of the Ford Motor Co., for the attention of the Aeronautic Divisions: common sections of duralumin; interior fittings for trim, such as locks, hatch locks, and lamp bases; aluminum and duralumin rivets.

Aircraft-Engine Division Activities

The Aircraft-Engine Division subjects were presented to an open meeting for discussion and for action on each subject by members of the Division, who were present in a sufficient number to form a quorum of the Division. The reports as approved will therefore be submitted to the Standards Committee.

Spark-Plugs

O. C. Rohde, Chairman of the Subdivision on Aeronautic Spark-Plugs, submitted the following report at the meeting:

We recommend that the following items be added to or changed in the Metric Spark-Plug Standards, as now found in the HANDBOOK:

The diameter of opening or well in which the plug is seated shall be 1⅜ in.

The over-all length of aeronautic spark-plugs shall be 2⅝ in., maximum. The distance from plug or cable terminal to the nearest metallic object shall be ¾ in., minimum.

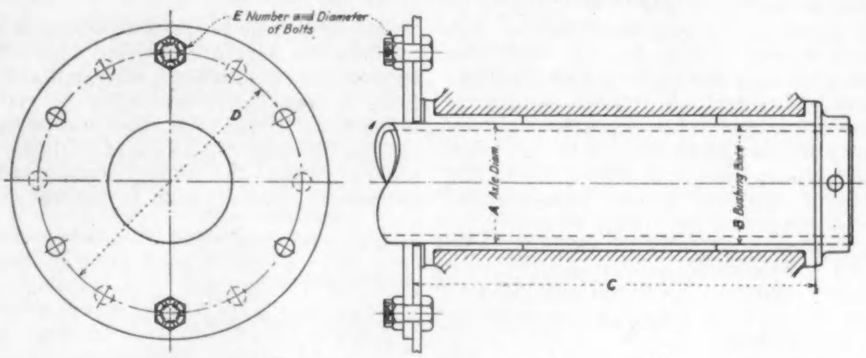
One-inch hexagon shall be standard. If smaller hexagon is desired it shall be 11/16 in.

The distance from the gasket seat to the end of the shell shall be ½ in.

The standard terminal for unshielded

AIRPLANE-WHEEL HUBS AND AXLE-ENDS, PLAIN BEARING

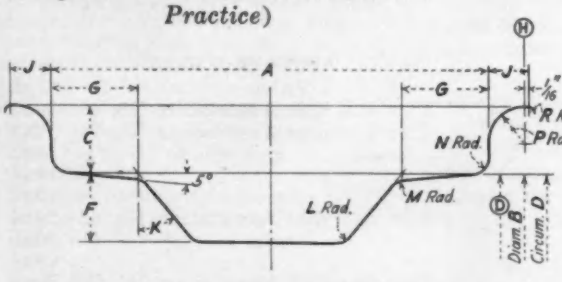
(Proposed S.A.E. Recommended Practice)



Wheel Size	Nominal Axle-Tube Diam. eter	*A* Finished-Axle Diameter-Tolerance +0.001−0.001	*B* Bushing-Bore Diameter-Tolerance +0.001−0.000	*C* Hub Length	*D* Bolt Circle	*E* Bolts No.	*E* Bolts Diam.
10x3	¾	0.750	0.753	4			
14x3	¾	0.750	0.753	4			
18x3	1¼	1.250	1.254	5	4	6	1/4
24x4	1½	1.500	1.504	6 or 5	4	6	1/4
28x4	1¾	1.719	1.723	6	4	6	1/4
30x5	2¼	2.188	2.193	7¼	4¾	6	3/8
32x6	2¼	2.188	2.193	7¼	4¾	6	3/8
36x8	2¾	2.688	2.693	8½	5¾	12	3/8
44x10	3¼	3.188	3.194	10	8	12	9/16
54x12	4	3.937	3.944	12	8	12	9/16

AIRPLANE RIMS

(Proposed S.A.E. Recommended Practice)



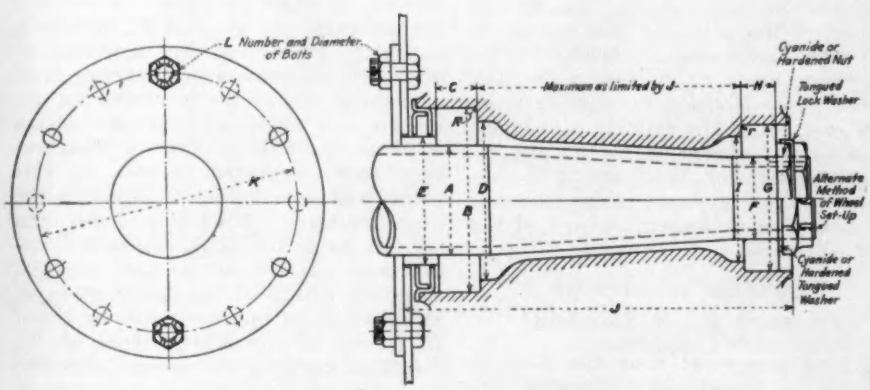
AIRPLANE STRAIGHT-SIDE DROP-CENTER RIM DIMENSIONS

Rim Size	*A* Width between Flanges	*C* Flange Height	*F* Well Depth	*G* Ledge Width	*J* Minimum	*K* Degrees	*L* Radius	*M* Radius	*N* Radius	*P* Radius of Flange	*R* Radius, Minimum
3	2⅛	7/16	17/32	17/32	5/16	25°-12′	1/8	7/32	3/32	1/4	3/64
4	2½	9/16	19/32	5/8	11/32	27°	1/8	1/4	1/8	9/32	3/64
5	3	5/8	21/32	3/4	3/8	27°	1/8	1/4	5/32	5/16	3/64
6	4	11/16	23/32	7/8	7/16	38°	3/16	1/4	5/32	3/8	1/16
8	5	13/16	27/32	1	1/2	38°	3/16	1/4	7/32	7/16	1/16
10	6	15/16	31/32	1³⁄₁₆	9/16	38°	3/16	1/4	1/4	1/2	1/16
12	7	1¹⁄₁₆	1³⁄₃₂	1⅜	5/8	38°	3/16	1/4	1/4	9/16	1/16

Airplane Tire and Wheel Combinations
(Proposed S.A.E. Recommended Practice)

Standard Wheel Size	Standard Tire Size	Oversize Tire for Extra Cushioning	Recommended Maximum Static Load, Lb.	Inflation Pressure Lb. per Sq. In.	Maximum Tire Deflection, Per Cent	Static Load to Completely Collapse Tire at Foregoing Inflation, Lb.	Minimum Wheel Strength, Lb. Radial	Minimum Wheel Strength, Lb. Side
10x3	10x3		325	50	20.0	1,700		
14x3	14x3		400	50	25.0	1,900	3,000	
		16x4	400	33	25.0	2,500		
18x3	18x3		525	50	25.0	2,100	5,000	2,000
		20x4	525	34	25.0	2,600		
24x4	24x4		850	50	27.5	3,500	7,000	2,500
		26x5	850	32	27.5	3,600		
28x4	28x4		1,000	50	27.5	3,700	8,500	3,000
		30x5	1,000	32	27.5	3,800		
30x5	30x5		1,600	50	27.5	5,100	11,000	3,300
		32x6	1,600	38	27.5	6,200		
32x6	32x6		2,200	55	27.5	8,000	13,500	4,050
		36x8	2,200	35	27.5	9,800		
36x8	36x8		4,000	60	27.5	13,500	20,000	6,000
		40x10	4,000	47	27.5	16,500		
44x10	44x10		6,300	65	27.5	20,800	33,000	9,900
54x12	54x12		10,000	70	27.5	35,000	50,000	15,000
		54x12	10,000	47	27.5	42,000		

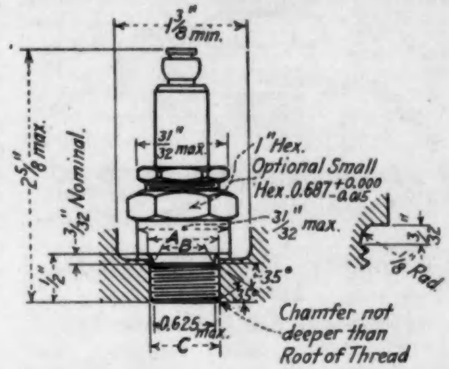
Wheel Hubs and Axle-Ends, Antifriction Bearing
(Proposed S.A.E. Recommended Practice)



aeronautic spark-plugs shall be as previously submitted to the Aircraft-Engine Division with a few minor dimensional changes.

This report resulted from a meeting of the Subdivision in Detroit on April 9. The final specifications, as approved by the Aircraft-Engine Division, follow. There was considerable discussion as to whether the S.A.E. Standard on Aeronautic Spark-Plugs should contain more than one hexagon

Aeronautic Spark-Plug
(Proposed S.A.E. Standard)



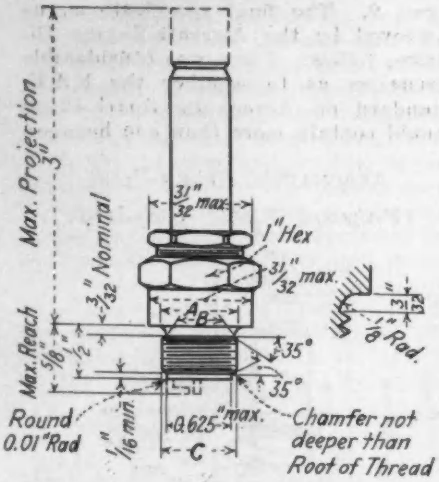
size and it was decided that, since many engine manufacturers desire to use the so-called midget-type spark-plugs, an alternate small hexagon size should be given in the specifications. Also, because the proposed aeronautic spark-plug and the existing specification for metric spark-plugs on p. 141 of the 1929 edition of the Handbook are identical in the majority of dimensions, the Subdivision recommended a slight revision of this latter specification so that there shall be no discrepancies between the aeronautic standard metric spark-plug and the metric spark-plug as used for automobile and motorcycle work. The revision is minor, consisting only in the change of the length from the gasket seat to the end of the shell to bring

Wheel Size	A Inner-Axle Diameter Tolerance +0.000—0.001	B Wheel-Bore Diameter Tolerance +0.000—0.001	C Inner Bearing Width	R Radius of Hub-Bore Inner-Position Tolerance +0.000—1/64	D Inner-Bearing Shoulder Diameter Maximum	E Spacer Outside Diameter	F[a] Outer-Axle Diameter Tolerance +0.000—0.001	G[a] Wheel-Bore Diameter Tolerance +0.000—0.001	H[a] Outer Bearing Width	r[a] Radius of Hub-Bore Outer-Position Tolerance +0.000—1/64	I[a] Outer-Bearing Shoulder Diameter, Maximum	J Wheel Hub Length	K Bolt Circle	L Bolts No.	L Bolts Diam.
Tail Wheels															
10x3	0.750	1.624	15/32	1/32	1⅜	1	0.750	1.624	15/32	1/32	1⅜	4[b]			
14x3	0.750	1.624	15/32	1/32	1⅜	1	0.750	1.624	15/32	1/32	1⅜	4			
Landing Wheels															
18x3	1.250	2.312	37/64	1/32	2	1⅝	1.000	1.968	17/32	1/32	1¾	5	4	6	1/4
24x4	1.500	2.687	5/8	3/64	2⅜	1⅞	1.000	1.968	17/32	1/32	1¾	6 or 5	4	6	1/4
28x4	1.500	2.687	5/8	3/64	2⅜	1⅞	1.000	1.968	17/32	1/32	1¾	6	4	6	1/4
30x5	2.000	3.374	3/4	3/64	3	2½	1.500	2.687	5/8	3/64	2⅜	7¼	4¾	6	3/8
32x6	2.000	3.374	3/4	3/64	3	2½	1.500	2.687	5/8	3/64	2⅜	7¼	4¾	6	3/8
36x8	2.500	4.124	27/32	1/16	3¾	3	2.000	3.374	3/4	3/64	3	8½	5¾	12	3/8
44x10	3.000	4.781	31/32	1/16	4¼	3 9/16	2.500	4.124	27/32	1/16	3¾	10	8	12	9/16
54x12	3.750	5.843	1⅛	3/32	5¼	4⅜	3.000	4.781	31/32	1/16	4¼	12	8	12	9/16

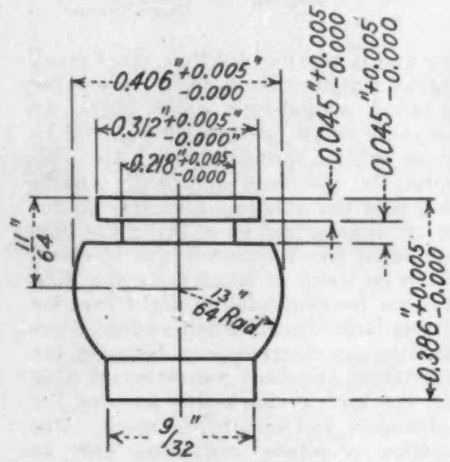
[a] Use of a tapered axle necessitating smaller outside bearing is optional. Straight axles should use the same outer bearing as inner bearing, as listed.
[b] Measurement J for tail wheels is taken from inside-fork faces.

this dimension in accord with present manufacturing practice.

METRIC SPARK-PLUG
(Proposed Revision)



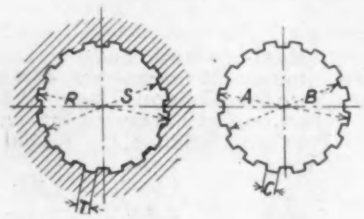
AERONAUTIC SPARK-PLUG BALL-TERMINAL
(Proposed S.A.E. Standard)

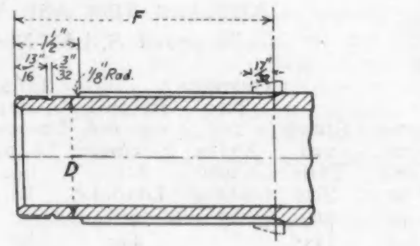


The report of the Subdivision also contained a recommendation, which was approved by the Division, for adoption of the following specification for a ball-type terminal for aeronautic spark-plug use.

Propeller-Hubs and Shaft-Ends

As considerable development has been carried on in large-size engines,





it has been thought desirable that the Aircraft-Engine Division should give consideration to adding to the present specification a No. 50 splined shaft-end and propeller-hub, the dimensions of which in general shall conform to the shaft in use on geared Hornet engines manufactured by the Pratt & Whitney Aircraft Co. This matter was discussed with particular reference to a drawing of such a shaft involving the dimensions in use at present, but it was felt that further study should be given to this subject, hence definite action was deferred to give companies an opportunity to consider the situation.

When the original specifications for the present splined shaft were submitted, the drawings contained two dimensions providing the location of the rear cone. The final specification, as adopted last June, omitted these dimensions as unnecessary, but at the request of the propeller manufacturers and some of the engine manufacturers, they were again submitted to the Aircraft-Engine Division for consideration as a revision of the existing standards. As a result, dimension F and the attendant dimension 17/32 are to be submitted to the Standards Committee as a revision of the standard on p. 2 of the 1929 edition of the HANDBOOK.

PROPELLER BLADE-ENDS
(Proposed S.A.E Standard)

It was suggested that the Society, through its Standards Committee, approve as S.A.E. Standards the Army and Navy Standards on propeller blade-ends and propeller-blade clamp-ring bolts and nuts. These reports were submitted to the Division by Lieut.-Com. C. H. Havill, of the Bureau of Aeronautics, Navy Department, and the specification as printed on p. 341 of the

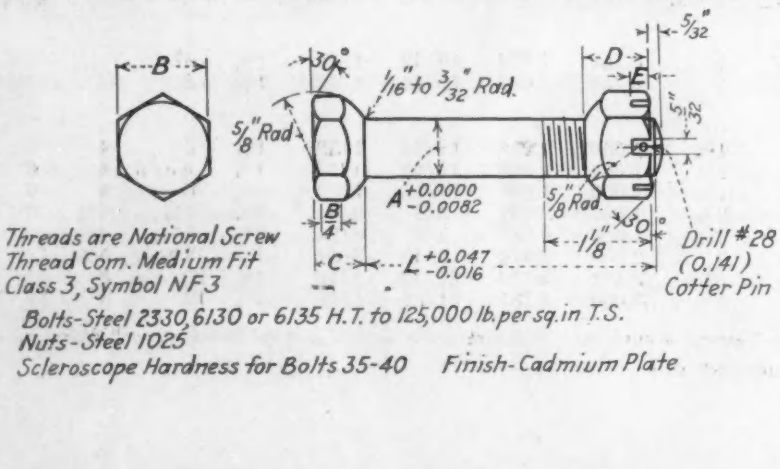
Shaft Number	F
10	5⅝
20	6⅜
30	6½
40	6⅛

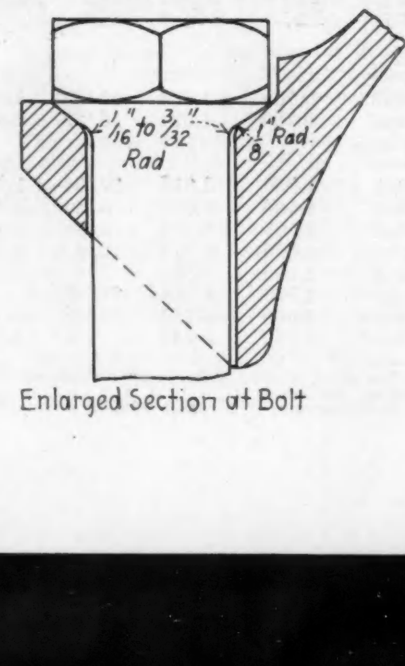
March issue of THE JOURNAL was approved by the Division for submission to the Standards Committee as an S.A.E. Standard.

The question of the adoption of propeller-blade clamp-ring bolts and nuts caused considerable discussion as to the suitability of the design. It was contended by Arthur Nutt, of the Curtiss Aeroplane & Motor Co., that the design of clamp-ring as submitted was not satisfactory. However, it was argued by some of the other manufacturers and by representatives of the Army and Navy that it represented the best practice known at present and therefore, while perhaps not suitable for adoption as an S.A.E. Standard, should be considered and approved as an S.A.E. Recommended Practice until something better is developed or revisions are made so that the design shall be suitable. Division members only were requested to vote on this point, and the motion to approve the propeller-blade clamp-ring bolts and nuts as an S.A.E. Recommended Practice was carried by a close margin. Complete details of the specification on clamp-rings as approved will be found on p. 340 of the March issue of the S.A.E. JOURNAL. A revised illustration of the bolt and nut is given below.

TACHOMETER DRIVES
(Proposed Revision)

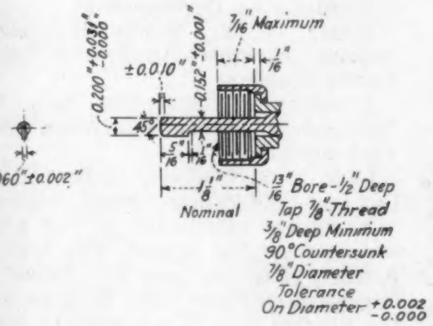
Discrepancies have existed for some time past between the S.A.E. and the Army Air Corps specifications for the

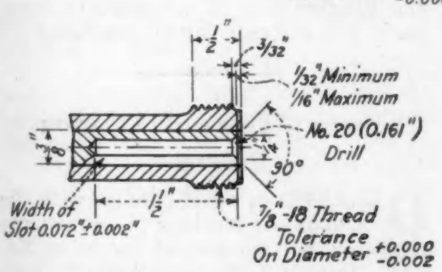




Enlarged Section at Bolt

engine end of tachometer drives, and this has caused considerable confusion in the application of tachometer shafts to engines. The principal difference was in the diameter of the tang and, to eliminate the difficulties caused, a revision of the present specifications of the engine end of the tachometer drive shaft and the corresponding engine connections, on pp. 8 and 9 of the 1929 edition of the HANDBOOK, was submitted by Mr. Nutt to the Division for consideration. The illustrations of the proposed revision, which also provides for the elimination of many unnecessary details having no bearing on interchangeability, are shown herewith. In approving these changes, the Division requested that the correct tolerances be shown on the thread-pitch diameter; namely +0.000 −0.002 on the male thread and +0.002 −0.000 on the female thread.

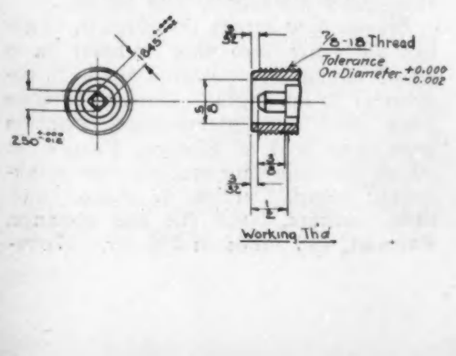




In addition to these revisions, the subdivision considering this subject deemed it advisable to simplify the drawings of the instrument end of the tachometer shaft and the connection as shown on p. 7 of the 1929 edition of the HANDBOOK, it being felt that the present illustration shows many details that have no bearing on the interchangeability or the standardization of the connection.

INSTRUMENT-END TACHOMETER DRIVESHAFTS

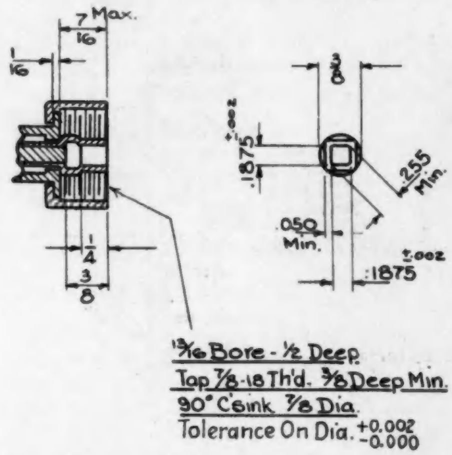
(Proposed Revision)



TACHOMETER-SHAFT CONNECTION

(Proposed Revision)

As the revised illustrations had not been submitted previously to the Division, although no change of dimensions is involved, it was requested that they be submitted to the Division by letter-ballot for examination so that, if approved, they can be presented to the



Standards Committee for consideration in June for approval as a new S.A.E. Standard on Tachometer Drives.

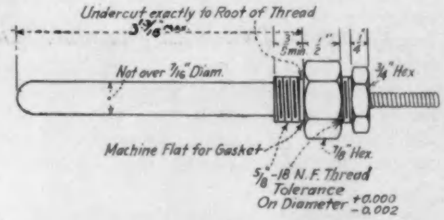
THERMOMETER BULBS

(Proposed S.A.E. Standard)

The proposed specification on thermometer bulbs, as published in the April issue of the S.A.E. JOURNAL, was submitted for consideration after one or two minor revisions had been made in the dimensions. The correct specification is illustrated herewith, it being understood that when finally submitted to the Standards Committee the toler-

THERMOMETER BULB

(Proposed S.A.E. Standard)



ances on the pitch diameter shall be added in accordance with the following note:

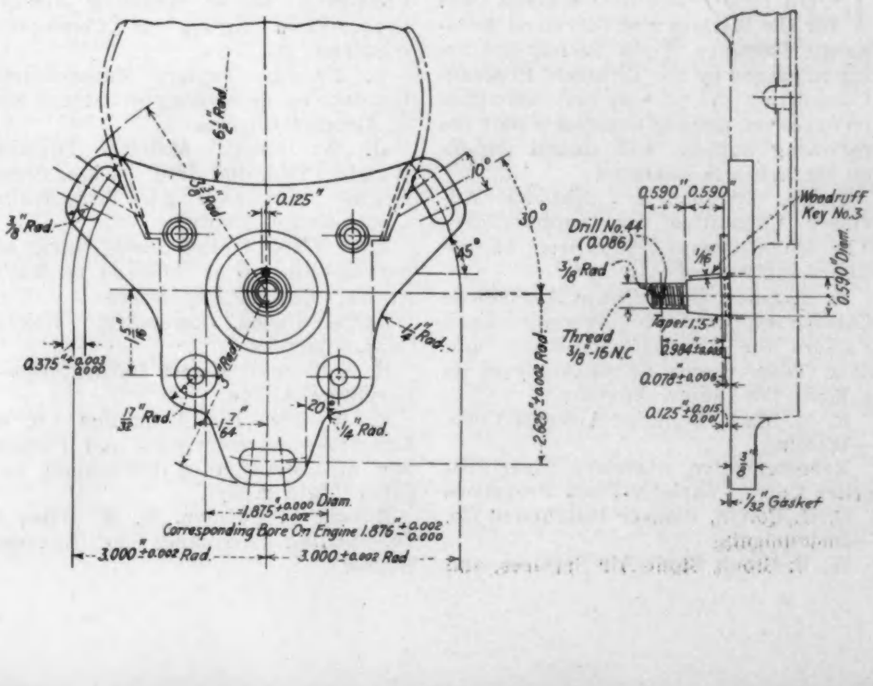
Note.—The tolerances on the pitch diameter of the ehermometer-bulb thread are +0.000 —0.002, and on the pitch diameter of the corresponding engine thread +0.002 —0.000.

FLANGED MAGNETO-MOUNTINGS

(Proposed S.A.E. Standard)

A subject of major interest to engine and magneto manufacturers which has been under discussion for some time is flanged magneto-mountings. Several such mounting flanges, of the three-bolt and two-bolt type, are in existence. Discussion on the subject at the meeting centered around the diameter of the pilot, Mr. Nutt contending that the pilot on both the small magnetos with the two-bolt flange and the larger magnetos with the three-bolt flange should be identical. As the small magnetos are manufactured with a 3-in. pilot and a two-bolt flange, this would of necessity, if approved, provide large magnetos with the 3-in. pilot and some type of three-bolt flange. Mr. Nutt also maintained that small magnetos should have a three-bolt flange designed so that if desired it can be mounted

PROPOSED THREE-BOLT FLANGED MAGNETO-MOUNTING AND CONNECTION

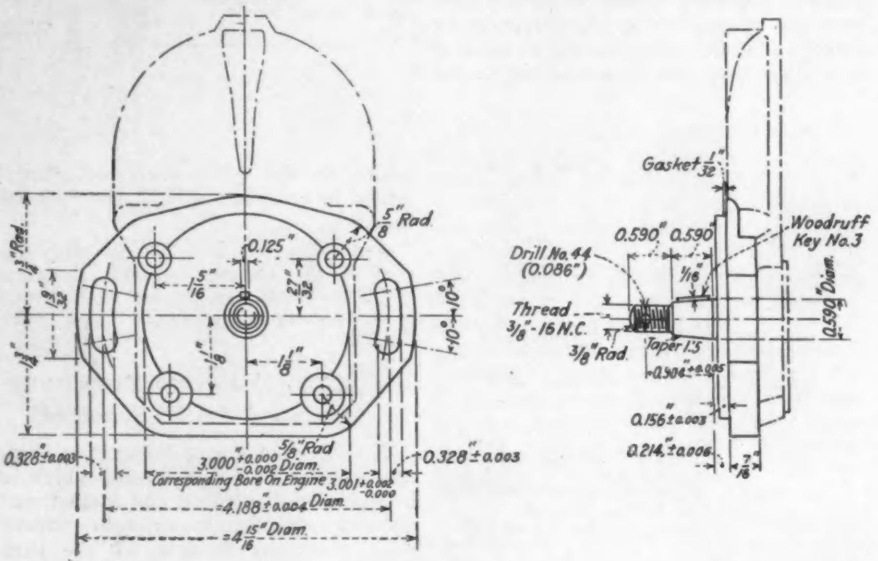


on the present two-bolt mounting without using the third mounting hole.

Prevailing opinion, however, was in favor of the two-bolt mounting similar to that now in use on the smaller magnetos with a 3-in. pilot, and for a three-bolt mounting with the mounting holes space 120 deg. apart for larger magnetos with a pilot of 1⅞-in. diameter. These two designs are in accord with the flanges on magnetos now in fairly large production, and after considerable further discussion the Division voted to approve the two flanges as shown.

Consideration of standard engine tests was postponed to a later date, after the Army and Navy and the Department of Commerce, through the Bureau of Standards, has had an opportunity to decide various questions and to agree upon a number of points on which there is now a difference of opinion.

PROPOSED TWO-BOLT FLANGED MAGNETO MOUNTING AND CONNECTION



Edward P. Warner—Economic Relationship of Speed and Weight in Air Transportation

Other Papers Desired

Others whom the Committee has invited to present papers on important problems of the industry as indicated are:

T. E. Tillinghast, Capt., Materiel Division, Wright Field—Engine Testing

T. P. Wright, Curtiss Aeroplane & Motor Co.—Geared Engines and Their Effect on Performance

I. Sikorsky, Sikorsky Aviation Corp. —Foreign versus American Aircraft-Development

Sherman Fairchild, Fairchild Aviation Corp.—Potential Demand for Privately Owned Aircraft

Lieut. James Doolittle, Guggenheim Fund for the Promotion of Aeronautics —Blind-Flying Developments

Major G. E. Woods Humphrey, Imperial Airways—Air-Transportation Traffic Problems

Ferrero de Gubernatis, Soc. An. Navigazione Aerea—Overwater Air-Transportation

Capt. L. M. Woolson, Packard Motor Car Co.—The Packard Diesel Engine

A general symposium is also being arranged on the subject, The Life of Aircraft Engines and the Effect of Operation on Their Life. Both sides of the question will be discussed by operators and aircraft-engine engineers.

Wichita and Cleveland Meetings

Authors and Their Subjects Assured for Technical Sessions of Coming Aeronautical Gatherings

FOUR or five technical sessions each for the Wichita and Cleveland Aeronautic Meetings of the Society are being arranged by the Technical Program Committee. At present the Committee has received definite assurance that the following authors will submit papers on the subjects indicated:

J. W. Crowley, Jr., National Advisory Committee for Aeronautics—The Quantitative Comparison of the Characteristics of Aircraft

A. S. Niles, Guggenheim Aeronautic Laboratory, Stanford University—Load Factors for Aircraft Structures and Load Tests versus Stress-Analyses as a Basis for Design Approval

R. M. Mock, Bellanca Aircraft Corp. —Welding

Representative, Standard Steel Propeller Corp.—Variable-Pitch Propellers

C. H. Colvin, Pioneer Instrument Co. —Instruments

W. B. Stout, Stout Air Services, and Charles T. Porter, Keystone Aircraft Corp.—Load Rating of Commercial Airplanes

C. Fayette Taylor, Massachusetts Institute of Technology—Cost and Size of Aircraft Engines

G. W. Frank, Materiel Division, Wright Field, and J. H. Geisse, Comet Engine Corp.—High-Temperature Liquid-Cooled Engines

L. D. Webb, United States Naval Air Service—Design as Affected by Naval Aircraft-Carrier Experience

Ralph Upson, Aeromarine Klemm Corp.—Airfoils

H. S. Cooper, Kemet Laboratories—Beryllium Alloys

E. H. Dix, Jr., Aluminum Co. of America—Characteristics and Prevention of Corrosion of Duralumin and Other Light Alloys

Russell L. Putnam, A. W. Shaw & Co.—Selling Airplanes to Business Houses

Twenty Years of Aviation Progress

DELAYED to avoid conflict with the Aeronautic Meeting in Detroit, the Canadian Section met at the King Edward Hotel in Toronto on April 17, with 48 members and prospective members in attendance. The meeting was briefly addressed by Capt. Earl Hand, president of the Toronto Flying Club, and Carter Guest, its chief instructor. The principal speaker was Prof. J. H. Parkin, who is in charge of aeronautic and research work in the faculty of applied science and engineering of the University of Toronto. He expressed his belief that the Society is the strongest and most important organization in America dealing with aviation, and said that it is not unlikely that aeronautical engineering may in the future become the major activity of the Society.

Bleriot flew across the English Channel 20 years ago this summer in a small monoplane powered by a three-cylinder 35-hp. engine. During the same year, the first international aviation meet was held at Rheims, France, at which the following records were established: speed, Curtiss, 47 m.p.h.; altitude, Latham, 508.5 ft.; and distance, Farman, 118 miles in 3¼ hr. Corre-

sponding records today are 319.57 m.p.h., 38,800 ft., and 4417 miles.

Important directions of present development were listed by Professor Parkin as metal construction, multiple engines, oil engines, and improved control or stability at low speed. He said that metal construction has still a long way to go in making use of the metal sheeting for carrying stress.

Progress in powerplants was noted in two directions, one exemplified by Napier, Packard, Allison, and Isotta-Fraschini engines, each of 1000 hp. or more; and the other by monoplanes of moderate size, one powered with three Cirrus engines and another by one 90-hp. and two 65-hp. Le Blond engines. In reciting the advantages of the oil engine, the speaker said that it is not a dainty feeder, but he expressed uncertainty as to the relative freedom from trouble of electric ignition-systems and Diesel injection systems. In mentioning the Maybach engine, he said that the two-stroke cycle should prove advantageous in an oil engine.

The address closed with a careful analysis of what had been observed at the recent aeronautic show in Detroit.

Metropolitan Aviation Meeting

Tail-Spinning, Engine Cowling and Inspection Were Subjects at Initial Division Meeting

IT WAS a real aviation meeting that inaugurated the public activities of the Aeronautic Division of the Metropolitan Section in the Colonial Room of the Park Central Hotel, Thursday evening, April 4. Almost half of the 200 men who registered are connected directly with aviation, most of them with manufacturers of airplanes, engines or parts.

And some of them are not limited in their flying to mere flights of imagination. They not only lightly bandied technical terms about the mechanics of why a plane will spin or will it? They talked nonchalantly about their experiences and experiments in tail-spinning several thousand feet toward the earth and whether, when spinning backward, wrong side up and crosswise, they have found it better to push the stick toward the center of the spin, step on her tail or apply the brakes.

Both Temple N. Joyce, of the Berliner-Joyce Corp., Baltimore, and Paul Hovgard, of the Keystone Aircraft Corp., Bristol, Pa., told of their experiences in the air while experimenting with spinning planes. Although differences of opinion appeared in the discussion, Chairman E. S. Land had no difficulty in keeping order.

Vice-Chairman George Round presided at the opening of the meeting, and introduced Captain Land, who, as Chairman of the Aeronautic Division, made an announcement of the next meeting of the division on May 23 and presided in a very efficient manner.

Spinning and Production Problems

In the paper on Spinning Characteristics of Airplanes, which was presented by Dr. Michael Watter, of the Chance Vought Corp., an appeal was made for some basic improvement in airplanes that will correct their tendency to spin. Dr. Watter's paper appears in this issue of THE JOURNAL, beginning on page 474.

Next came a paper entitled Quality Problems in Aircraft-Engine Production, delivered by A. V. D. Willgoos, chief engineer of the Pratt & Whitney Aircraft Co. Intended primarily as a paper on inspection, it includes an outline of design principles to facilitate inspection. Mr. Willgoos remarked on the close association between the engineering and inspection departments, which is facilitated in his organization by placing the inspection department under the direction of the chief engineer, rather than under the factory manager.

Rough material is inspected with the same care as finished parts, and records are kept which show the heat number of the steel used in each forging, with certified copies of physical tests. Each master connecting-rod and crankshaft is given a serial number. Similar careful records are kept of bar stock, and piston-pins are given serial numbers through which the chemical and physical history can be traced.

Inspections during processes are made as a matter of economy and in cases of parts that are permanently attached to each other during fabrication, as are the cylinders and cylinder-heads. Finished parts are inspected, as a matter of course, and even the packing is a subject of inspection. Mr. Willgoos emphasized the importance of thorough inspection for the sake of the reputation of the manufacturer and the welfare of the aeronautic industry.

K. M. Lane, of the Wright Aeronautical Corp., the last scheduled speaker, gave an extemporaneous talk on the engine cowling that has been designed by the National Advisory Committee for Aeronautics. He said that an impression has been created that engine manufacturers are opposed to this cowling, but he cannot imagine that any manufacturer of air-cooled radial engines should be opposed to it, because it is the one thing that will make it possible for such engines to compete successfully in speed with the water-cooled V-engine.

Facts About Radial Engines

Pratt & Whitney Engineer Addresses 146 Members and Guests at Milwaukee Section Aeronautic Meeting

INTEREST in aeronautics at Milwaukee was indicated by an attendance of 146 at the aeronautic meeting of the Section held April 3 at the Milwaukee Athletic Club. All but 22 of these attended the dinner which preceded the meeting. E. A. Rider, of the Pratt & Whitney Aircraft Co., delivered an illustrated paper on the Aeronautic Powerplant, which was followed by meaty discussion.

Mr. Rider, in opening his address, presented comparative figures for engines of various classes as to weight and cost per horsepower, thermal efficiency, and number of miles of operation per overhaul. The usual cost of $18 per horsepower for airplane engines is much lower than for marine steam and Diesel engines. The miles per overhaul of the aircraft engine were given as 30,000 to 50,000 miles, compared with 30,000 miles for marine engines, 100,000 for the locomotive, and 10,000 for the automobile engine.

Precedents have been lacking for the design of radial engines; in particular, for the arrangement of the connecting-rods and the lubrication. In spite of the familiarity of the present fixed radial air-cooled engine, Mr. Rider said that many visitors at aeronautic shows think that the cylinders rotate.

A number of views of Wasp and Hornet engines and their details were shown on the screen and described by the speaker. Some of the slides showed changes in design, such as that from a master connecting-rod with a cap held on by four bolts to the present one-piece construction. This change has made higher speeds safe and increased the durability because of the lighter rotating parts. The front end of the crankshaft is forged in a way to give continuous grain-flow from the main bearing to the crankpin, and the rear portion is joined to it with splines

(*Concluded on p.* 545)

Summer Meeting Technical Program

Paper on Combustion-Head Design by W. A. Whatmough, English Engineer—Afternoons Reserved Solely for Outdoor Events

COMBUSTION-HEAD design and mixture distribution are the two most important subjects before the automotive industry at present, in the opinion of the Motor-Vehicle Committee. Both of these subjects will be discussed at the Summer Meeting, the former by W. A. Whatmough, a consulting engineer of England, whose views have been expounded from time to time in *The Automobile Engineer*, of England. Mr. Whatmough is coming to this Country at the invitation of the Motor-Vehicle Committee especially to attend the Summer Meeting, and the subject of his paper will be Combustion-Head Design in Theory and Practice.

His paper will be discussed by R. N. Janeway, who submitted a paper presenting his own views on the subject at the February meeting of the Detroit Section. Mr. Janeway's paper is printed in this issue of THE JOURNAL, beginning on p. 498.

Mr. Whatmough's paper will be the only one to be presented at the Combustion Session, to allow ample time for general discussion.

A Mixture-Distribution Conference

Although opinions differ greatly regarding mixture distribution, the Committee has been unable to obtain comprehensive papers on the subject to warrant a set program. Therefore the subject will be considered at a Mixture-Distribution Conference at which the discussion will be led by several American engineers, as indicated in the accompanying program. In view of the differences of opinion existing, it is expected that this session will be one of the most valuable ever staged by the Society.

Members of the Society will be particularly pleased to learn that Paul G. Hoffman, vice-president of the Studebaker Corp. of America, will speak at the Tuesday evening session on the subject, What I Think Engineers Are Good For—and How. This session, which is sponsored by the Meetings Committee under the chairmanship of John A. C. Warner, is a continuation of the series of Business-of-Engineering Sessions started in Quebec last summer. Norman G. Shidle, of the Chilton Class Journal Co., will be chairman of the Session. Mr. Hoffman, who is in charge of Studebaker sales, will bring an entirely fresh viewpoint to S.A.E. meetings. The Meetings Committee is to be congratulated on being able to include Mr. Hoffman in the Summer Meeting program.

Only Morning and Evening Sessions

The technical program has been arranged so that all specialized subjects will be discussed at morning sessions, the afternoons being reserved entirely for the various tournaments and the evening sessions devoted to more general topics that will interest everyone. A feature of the program is the Body Dinner, which will be held Wednesday evening, this dinner meeting being sponsored by the Detroit Section Body Division. The speaker of the evening will be announced later.

The technical program warrants every member's attendance, the number of sessions having been limited to make it possible for each member to attend all of the sessions that are of primary importance to him.

Golf Tournament Plans

Plans for the Golf Tournament are being whipped into shape under the chairmanship of J. B. Shea. This year the tournament will be based entirely on medal play, a qualifying round of 18 holes being played on the first day, with 18 additional holes on the second and third days, the final scores being based on the total score for the 54 holes. With the exception of the championship flight, the club handicaps of the players will be used. There will also be blind bogey tournaments on the third and fourth days.

This year the Meetings Committee is awarding a trophy to the winner of the golf tournament, this trophy to be the property of the Society but awarded each year to the winner of the tournament.

Sightseeing Trip

The Meetings Committee is arranging a sightseeing trip for the afternoon of the first day, this trip to take in Lake Placid, Wilmington Notch, Paul Smiths, High Falls and other interesting points. On the second day there will be a water carnival and on the third day field sports wherein skill and strength will play no part. Special notices regarding Field Day events will be issued to members making reservations for the Summer Meeting at Saranac.

Among the social events planned for the evenings is a barn dance on the first evening, informal dancing on the second evening, and the grand ball on the third evening. Special costumes will be required for the barn dance.

The usual tennis, archery and other events are being planned, entry blanks for these being sent to all members making reservations.

See Pages 50 and 51 of Advertising Section for

Saranac Inn Announcement

Tentative Summer Meeting Program

Saranac Inn June 25-28, 1929 Saranac Lake, N. Y.

Tuesday, June 25

8:30 P. M.—BUSINESS-OF-ENGINEERING SESSION

(Sponsored by the Meetings Committee)

N. G. Shidle, *Chairman*

What I Think Engineers Are Good For—and How—Paul G. Hoffman, Vice-President, Studebaker Corp. of America.

Wednesday, June 26

9:30 A. M.—COMBUSTION SESSION

(Sponsored by the Motor-Vehicle Committee)

Combustion-Chamber Design in Theory and Practice—W. A. Whatmough, Consulting Engineer, England

Written Discussion—R. N. Janeway, Consulting Engineer; Alex Taub, Chevrolet Motor Co.

9:30 A. M.—MOTOR-TRUCK DESIGN CONFERENCE

(Sponsored by the Transportation Committee)

F. K. Glynn, *Chairman*

Extending the Use of Motor-Vehicles beyond the Field of Transportation—T. C. Smith, Engineer, American Telephone & Telegraph Co.

7 P. M.—BODY DINNER

(Sponsored by the Detroit Section Body Division)

President W. R. Strickland, *Chairman*

(Speaker to be announced)

Thursday, June 27

9:30 A. M.—MIXTURE-DISTRIBUTION CONFERENCE

(Sponsored by the Motor-Vehicle Committee)

Discussion to be led by H. W. Best, Sheffield Scientific School; C. S. Kegerreis, Tillotson Mfg. Co.; J. B. McCauley, Chrysler Motors; P. S. Tice, Stewart-Warner Speedometer Corp.; C. L. Petze, Massachusetts Institute of Technology

9:30 A. M.—TRANSPORTATION SESSION

(Sponsored by the Transportation Committee)

H. F. Fritch, *Chairman*

Long-Distance Motorcoach Transportation—R. E. Plimpton, Associate Editor, *Bus Transportation*

Heavy-Freight Haulage—Nathaniel Mallouf, Mallouf Haulage & Maintenance Co.

8:30 P. M.—AIRSHIP SESSION

(Sponsored by the Aeronautic Committee)

Edward P. Warner, *Chairman*

Airship Transportation of the Future—V. R. Jacobs, Assistant Manager, Aeronautic Department, Goodyear Tire & Rubber Co.

Friday, June 28

9:30 A. M.—RESEARCH SESSION

(Sponsored by the Research Committee)

H. L. Horning, *Chairman*

Horsepower Correction for Atmospheric Humidity—Donald Brooks, Associate Engineer, Bureau of Standards

Volatility Data on Natural Gasoline and Blended Fuels—Dr. O. C. Bridgeman, Bureau of Standards

Present Status of Equilibrium Work at the Bureau of Standards—Dr. O. C. Bridgeman

Cooperative Fuel Research from 1922 to 1929—Dr. H. C. Dickinson, Bureau of Standards

Aeronautic Engineering

(*Concluded from p. 543*)

and two cylindrical fits inside the crankpin.

When a 2-1 reduction is required for the propeller, a reducing gear is provided that is similar to a bevel-gear differential.

In reply to a question, Mr. Rider said that the company has not yet found an air-cleaner that is thoroughly satisfactory for the 1000 cu. ft. per min. of air required by an airplane engine. Centrifugal cleaners do not take out the fine dust. There was some discussion also of superchargers. Various degrees of supercharging can be provided for by supplying different gears.

It is hard for the aviator to adjust the carbureter for greatest economy, said Mr. Rider, as this is not secured by the leanest mixture on which the engine will run. The best way found is based on laboratory tests which show the comparative speed at the maximum power and the maximum economy. With this information, the carbureter can be adjusted for maximum speed in the air and the fuel reduced until the known speed for best economy is reached.

California "Air-Minded"

CALIFORNIA sunshine, air races, a nearly full moon, a visit to the Oakland Airport, a banquet attended by 1000, and an interesting paper all combined to render the April meeting of the Northern California Section a success. This gathering, which was held on April 20, attracted between 10,000 and 15,000 persons to the Airport, the largest number that ever visited it, according to Secretary W. S. Crowell.

After an afternoon spent in the open, the members and their guests gathered in Hangar No. 1 at 6:30 p.m. for the banquet. When appetites had been gastronomically satisfied, the feast continued, intellectually speaking, with the presentation of a paper on the History and Development of Aviation Engines, by Prof. C. L. Staub. Following the paper, a five-reel motion picture, The Flying Fleet, was exhibited by courtesy of the Metro-Goldwyn-Mayer Corp.

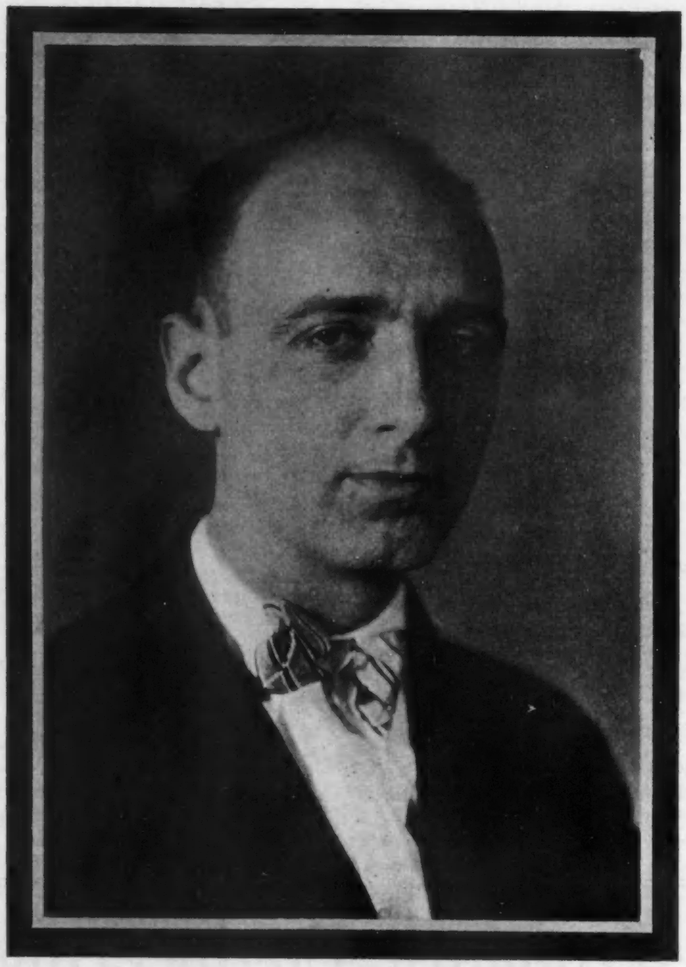
William Charles Naylor

WITH profound dismay and regret, members of the Society, especially members and guests who had attended the Aeronautic Meeting in Detroit during the week, learned of the deplorable accident at Ford Airport on Saturday, April 13, which resulted in the immediate death of A. H. Kreider, president of the Kreider-Reisner Aircraft Co., the death later in the same day of Capt. E. T. Bruce, of the All-American Aircraft Co., and the blotting out on Tuesday, in the Ford Hospital, of the exceptionally promising future of William C. Naylor.

Mr. Naylor had become endeared by his delightful personality and his unusual ability in his profession especially to members of the Detroit Section, in which he had been very active during the last two years. He had been enthusiastic for and largely instrumental in the formation of the Aeronautic Division of the Section and was elected Chairman of the Program Committee of the Division at its first meeting, on Feb. 27, 1928. He assumed the duties of this office with the energy and determination of the true airman and helped greatly to place the activities of the Division on a firm foundation. He had just been nominated by the Nominating Committee of the Section for the offices of Vice-Chairman of the Section and Chairman of the Aeronautic Division for the administrative year beginning in May, and it is the intention to honor his memory by electing him as nominated. Credit for the obvious success of the National Aeronautic Meeting in Detroit in April is due in large part to Mr. Naylor, who assisted actively in the arrangements for it and presided as Chairman at the first technical session on Wednesday, April 10. He was also deeply interested in helping young aeronautical engineers, and one of his latest proposals was a program to carry out such a movement.

From the highest executives to the mechanics in his chosen profession, Mr. Naylor had a host of friends, who admired him for his engineering ability and imagination and for his lovable, modest but confident and clear-headed personality that promised to carry him to the top in the aeronautic industry.

Cut off in the very prime of life, he had been, for the last nine months, chief engineer in charge of research and development work for the Stout Engineering Laboratories in Dearborn, Mich., where he was highly regarded and his loss is keenly felt, as in the opinion of the executives of the company no young man in the industry had a brighter outlook for the future than had Mr. Naylor.



WILLIAM CHARLES NAYLOR

Prior to his connection with the Stout interests, Mr. Naylor had been chief engineer for the Stinson Aircraft Corp., from 1926 to 1928, and designed the present Stinson Junior airplane. He was also largely responsible for the development of the Stinson Detroiter cabin airplane of the type flown by Schlee and Brock from Detroit to Tokio.

Mr. Naylor was perhaps the only well-known pilot of lighter-than-air craft who was an eminently successful designer of heavier-than-air craft. He had learned much from balloon navigation that was of value in his work of airplane designing, and was active in Detroit balloon circles, being vice-president and treasurer of the Detroit Balloon Club, Past President of the Detroit Flying Club, and Detroit representative in the last Gordon-Bennett balloon race, and had recently affiliated himself with the Detroit Air Yacht Club.

Mr. Naylor was born at Imlay City, Mich., in March, 1900, attended the Lapeer High School, and was graduated from the University of Michigan in 1922 with the degree of Bachelor of Science in aeronautic engineering. He was engaged in inspection and maintenance work with the Packard Motor Car Co. during part of 1923, in drafting and layout work for the Chevrolet Motor Co. for the following five months, next in drafting, layout, research and experimental work for the Aircraft Development Corp., and, from 1925 to 1928, in aeronautical designing as chief engineer for the Stinson Aircraft Corp. His last change, made last year, was to the W. B. Stout Aircraft Engineering Co.

In 1927 Mr. Naylor was elected to membership in the Society and in the same year joined the Detroit Section. Under his able chairmanship, the Commercial Aviation Session of the National Aeronautic Meeting of the Society in Chicago last December was very successful and interesting.

It was while engaged in the flying airplanes of all types exhibited at Detroit during the All-American Aircraft Show that Mr. Naylor met his death in the line of duty. A telegram of condolence sent by the Society to Mrs. W. C. Naylor in behalf of the members expressed appreciation of her husband's ability and his work for the Society.

Aeronautic Progress Shown at Detroit

(*Continued from p. 463*)

George S. Wheat, assistant to the president of the Pratt & Whitney Aircraft Co.

Recalls German Glider Flights

Toastmaster Edward P. Warner, in his opening remarks, paid the Detroit Section a compliment by stating that if the S.A.E. Aeronautic Meeting is to continue as an annual event it will be necessary for Detroit to build larger banquet halls. After announcing the sessions arranged for the following day, he expressed delight in seeing among those present a number of persons who have a distinguished place in the past records of gliding history, and recalled an interesting week he spent in southwestern Germany in 1922. On the evening he arrived in Gaarsfeldt, where a gliding meet had its headquarters, Herr Hentzen had just made the first 3-hr. glider flight in history. And a few days later Anthony Fokker made the first two-passenger glider flight from the summit of Wasserkuppe in a glider of his own design and construction.

Wright Brothers Medal Bestowed

This brief reminiscence led up to the matter of the honoring of the achievements of Orville and Wilbur Wright in their pioneer work in aviation and an expression of regret that Orville Wright could not be present at the meeting to witness the conferring of the Wright Brothers' commemorative medal, initiated four years ago by the Dayton Section but never previously awarded. It is now to be awarded annually, he said, for the best paper presented the preceding year at a meeting of the Society dealing with aerodynamics, structural theory or research, or airplane design or construction. As Howard E. Coffin, Chairman of the Board of Judges of Award, was unable to be present to make the presentation, it devolved upon the toastmaster, said Mr. Warner, to bestow the medal upon its winner for 1928, Lieut.-Commander Clinton H. Havill, U.S.N., for his paper on Aircraft Propellers delivered by him at the Chicago Aeronautic meeting last December and published in the S.A.E. JOURNAL for January, 1929. Those who have read the paper, said Mr. Warner, know that it sheds great credit on the author and the service to which he is attached, and thoroughly deserves the first award of the highest honor the Society has within its power to bestow in the aeronautic field.

Brigadier-General Gillmore, who was then introduced as the speaker of the evening, confessed that he had prepared a formal address but said that, after the splendid entertainment and in view of the interesting program of the evening, he was going to throw it into the discard and tell in an informal way about the work of the Material Division of the Air Corps at Wright Field at present and what those in charge hope to make it. The toastmaster, in introducing General Gillmore as "a very fortunate man," had referred to Wright Field as the sort of "a paradise to which aeronautic engineers would like to retire to spend as long a time as their imagination can span, which offers the opportunity for experiment, observation, and contact with and their development of novelties."

Dayton Citizens Donated Land

General Gillmore then told how in 1926 the Congress decided to do something for the Air Service of the Army and the Navy and created the offices of Assistant Secretary for Aeronautics of the Army, of the Navy and of the Department of Commerce. The Army and the Navy now recognize the importance of military aviation and are carrying on research and experimental work that will perfect itself as far as is possible with the engineering brains of the Country that are available to hire and that come to the Air Corps with their problems.

Because McCook Field, established during the war, was almost in the heart of Dayton, Ohio, and flying with bombs, guns and experimental equipment of all sorts had to be done over the thickly populated portion of the city, it early became evident that a safer field should be found. As a result of civic enterprise, the citizens of Dayton bought 5000 acres of land ideally located outside of the city and donated it to the Government for the use of the Air Corps, and the Government made liberal appropriations for the construction and equipment of wonderful laboratories.

General Gillmore had lantern slides and motion pictures of Wright Field and the new laboratories projected on the screen and gave a running description of them. The main laboratory building is 450 x 320 ft. in size and houses the airplane branch, the material branch, the armament branch, the photographic section and the designing section. In an adjacent dynomometer laboratory 16 powerplant stands have been built, three of which will take 1500-hp. engines, three 1000-hp. engines, and five will take 600-hp. engines. Future developments have been anticipated in the propeller testing installation in a nearby building. A 40-ft. propeller can be tested on one of the test blocks, which is provided with 6000 hp. A second block has 3000 hp., and the slipstream from one block

S.A.E. BOOTH AT DETROIT AIRCRAFT SHOW, WITH EXHIBITS OF PARTS MADE TO S.A.E. SPECIFICATIONS. (SEE P. 460)

flows onto the propeller on the next block, thus simulating actual flying conditions. A speed of 4500 r.p.m. can be developed on the smaller block.

Much interesting research is being carried on in the radio laboratory on blind flying, said General Gillmore, and it is hoped that the work with sensitive altimeters and other devices, together with efforts being made by the Guggenheim Fund, the Navy and the Army, will solve the problem of blind flying.

Men of the Materiel Division are very proud of the flying-field at Wright Field, which has a 6000-ft. runway on which a light car can be driven at 60 m.p.h.

Development for Civil Aviation

Research and development work go hand in hand, continued General Gillmore. Aeronautic equipment brought to the Division for military use is taken in hand by the engineering staff and efforts are made to develop it for civil and commercial aviation. Whereas a few years ago the sources of supply of aeronautic equipment could almost be counted on the fingers of two hands, the development of the industry has been so rapid that new devices are now being brought to Wright Field constantly and the problem of securing research and development engineers is solved. The Division, thinks the General, will soon be in position to recommend to the Congress that it be allowed to include in its estimates the necessary funds for development work, which in the past has been paid for out of production. The decision has been reached to pay for experimental work on contracts.

Among the slides shown was one of an aerial photograph taken near Rushville, Ind., by Captain Stevens from an altitude of 38,000 ft. and at a temperature of 60 deg. fahr. below zero. The area embraced in the very sharp picture is about 50 sq. miles. Another was a flashlight picture taken from a height of 6000 ft. This was exposed, developed in the airplane and dropped to the ground in a total of 8 min.

The address was concluded by references to the Division's new engine-cooling system using ethylene glycol as a coolant, whereby the radiator area is reduced 75 per cent, the parasitic drag of the radiator is reduced 80 per cent, the weight of the standard plane is cut down about 100 lb. and its speed increased by about 11 m.p.h. The boiling point of the coolant is 387 deg. fahr., making it an excellent antifreeze and enabling the engine to operate more efficiently at the higher temperature.

Drag Reduction and Spin Prevention

Dr. Lewis and Lieutenant Harper Describe Tests of N.A.C.A. Cowling and Wing Slots

IN OPENING the final session of the Aeronautic Meeting in the evening of April 10, Chairman Edward P. Warner referred in his brief introductory remarks to the revolutionary and epoch-making development of the new low-drag cowl by the National Advisory Committee for Aeronautics and said that if the Committee had done nothing else, this one accomplishment would justify every dollar that Congress has appropriated for it since it was started in 1915. He said he thinks it is safe to say that there never has been produced by any laboratory a single piece of research that transcends in immediate value to the aircraft industry, and to everybody who comes into contact with it, that which Dr. George W. Lewis was to present in some new and additional details, as well as in a summary of what has already appeared in print.

Effect of N.A.C.A.-Type Cowling

Dr. Lewis's description of the work of the Committee on the development of the N.A.C.A. cowling and the results that have been obtained with it was followed with absorbed interest. As explained by the speaker, this research work was undertaken as the result of the May, 1927, annual conference of the Committee with aircraft manufacturers at Langley Field. It was the consensus of opinion of those attending the conference that the most important problem the Committee could undertake in assisting the industry was the study of cowling and cooling radial air-cooled engines.

Analysis of the drag components of several typical airplanes fitted with such engines and using conventional cowling showed that the engines contributed from 15 to 25 per cent of the total parasite drag, as compared with 10 to 20 per cent caused by the radiators of water-cooled engines. It was evident, therefore, that to obtain the full advantages of air-cooled radial engines, it was necessary to find some way of reducing the drag, as a differential of 10 per cent of the total drag makes possible a 10-per cent increase in high airplane-speed with no increase in power.

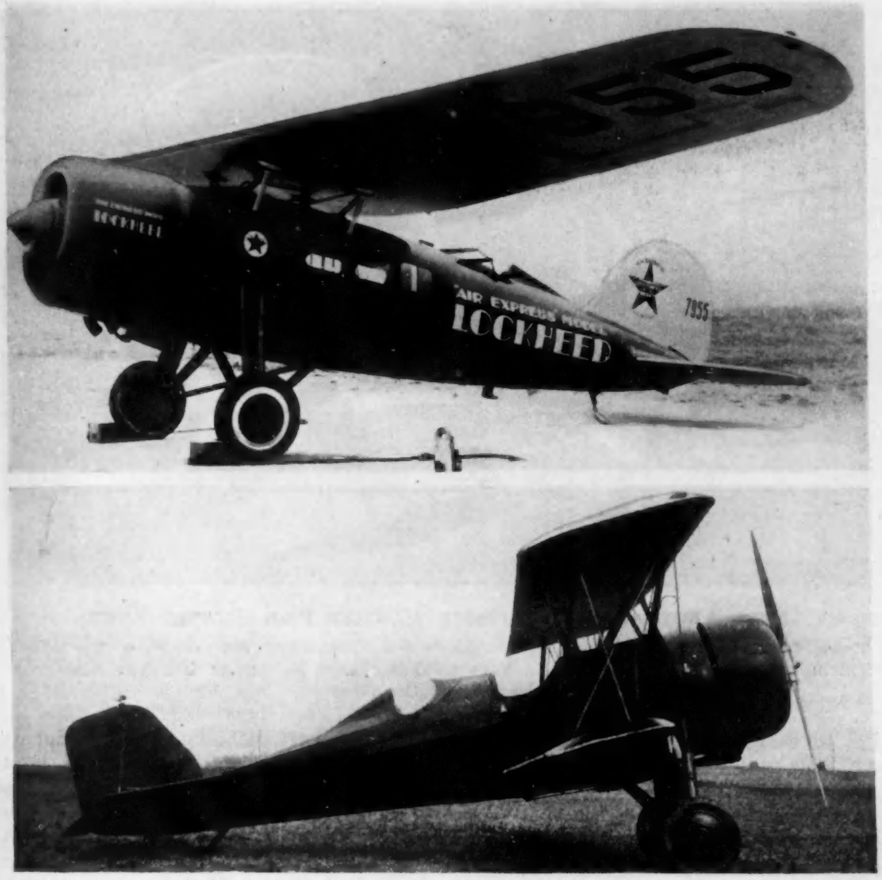
A program including 10 main forms of cowling, to be tested on a Wright J-5 engine in connection with two fuselages was undertaken, three types of cowling to be tested on an open-cockpit fuselage and seven on a cabin type. Dr. Lewis gave brief details of the way in which the tests were conducted and announced that detailed results of the investigation have been released in Technical Reports Nos. 313 and 314 of the National Advisory Committee for Aeronautics. His purpose at the meeting was to point out the high spots in the investigation and bring to attention the application of the results to commercial and military types of airplane. He emphasized that, in adapting the N.A.C.A. type of cowling, it is necessary, for each type of engine, to determine the correct amount of area at the entrance and exit of the cowl, and also that the fuselage and cowl together form a streamline body.

Surprising Results of Tests

The astounding efficiency of the N.A.C.A. type of cowling was shown in the tests by the fact that the drag of an open-cockpit plane fitted with the uncowled engine was 141 lb. at a speed of 100 m.p.h. and with conventional cowling was 136 lb., whereas with N.A.C.A. cowling it was reduced to only 73 lb. With the cabin fuselage, the drag was 125 lb. at 100 m.p.h. with uncowled engine; with conventional cowling that properly cooled the engine and the use of a spinner the drag was 106 lb.; and with N.A.C.A. cowling cut out around the magnetos to provide for their proper cooling the drag was reduced to 75 lb.

Drag of the cabin fuselage, with the engine removed and the nose rounded, was only 40 lb., or one-third of the drag with the uncowled engine. With complete streamline cowling covering the entire engine and separating the cooling air from the general flow around the fuselage body, the reduction in drag is about 2½ times as great as that obtained by the best conventional form of cowling.

First application of the new type of cowling was made on a Curtiss AT-5A pursuit-type airplane and resulted in an increase of 19 m.p.h. in speed. Another installation on the Lockheed Air Express, in which Captain Hawks established a new record for flight from Los Angeles to New York City, increased the maximum speed from 157 to 177 m.p.h. The results of other installations on various types of airplane were also given. The speaker particularly emphasized that, in installing the cowling, the recommendations of the Committee be followed carefully, and that if it is applied to any other than the Wright J-5 engine, careful design and development, with many changes and tests, will be required to obtain correct cooling. The Committee plans



LOCKHEED AIR EXPRESS AND PITCAIRN MAILWING AIRPLANES FITTED WITH N.A.C.A. DRAG-REDUCING COWLS

Capt. Frank Hawks, Who Established a Los Angeles-to-New York City Non-Stop Flight Record of 18 Hr. 13 Min. in This Lockheed Airplane Last February, Claimed the New Cowling Increased the Ground Speed from 157 to 177 M.P.H. The Cooling of the Engine Was Carefully Checked and Found To Be Very Effective

to extend its investigation to include cowling of other types of radial air-cooled engine.

Effects on Multi-Engine Planes

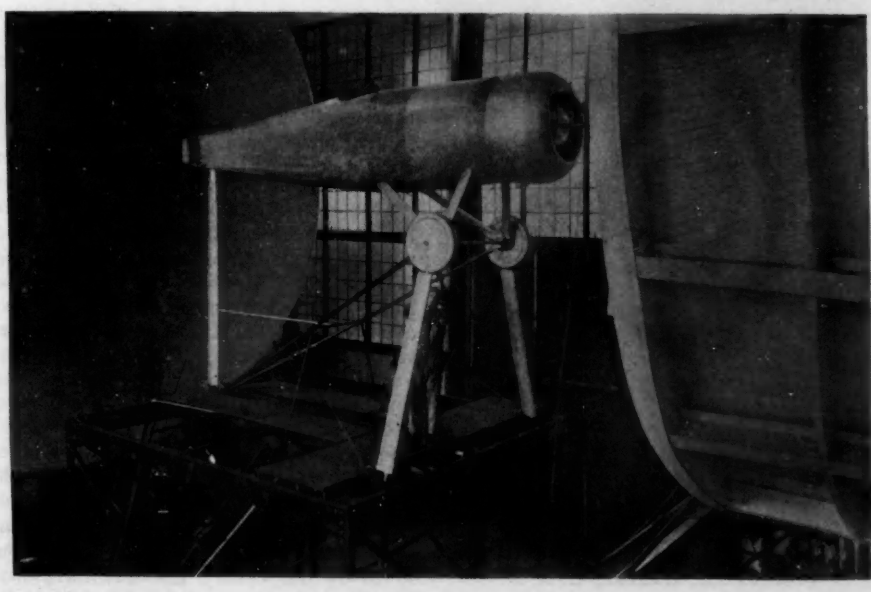
Some very surprising results were obtained in applying the cowling to multi-engine airplanes. Drag of the engine alone was found to be 42 per cent greater than that of a cabin fuselage with an uncowled engine on the nose. Drag of the conventional nacelle was 30 per cent greater than that of the cabin fuselage and engine combination with conventional cowling, and with the new complete form of cowling was only about one-fourth that of the conventional nacelle. Careful study of disappointing results obtained with a Fokker F-7 tri-engine plane indicated that the reason was the location of the nacelles close to the underside of the wings, with great resultant interference drag due to turbulence. When the nacelle was finally mounted in the leading edge of the wing and the cowl faired into the top surface of the wing, the wind-tunnel tests showed that at 100 m.p.h. and zero angle of attack the drag is 14 lb., or less than one-tenth of the drag indicated by the original installation.

An N.A.C.A. Technical Note will be released soon by the Committee discussing the location of completely cowled engine-nacelles with reference to the airplane wing. Dr. Lewis concluded with the statement that application of the cowling to multi-engine planes has many possibilities, and the gain in performance should be even greater than with single-engine airplanes.

Questioned on Special Points

A number of questions were asked after the conclusion of Dr. Lewis's address. Heraclio Alfaro inquired if some engines of the cam type would not show a considerable reduction in drag, as the diameter of this type is considerably less than that of the usual radial engine. Dr. Lewis responded that anything that can be done to cut down the total diameter is desirable, especially from the viewpoint of visibility, but whether the cam type of engine should be used raises a discussion of its advantages.

W. H. Barling and Ralph Upson raised a question as to how the cowling should be applied to a radial engine of few cylinders, say five or three; whether it would pay to extend the cowling around the whole group, if it should be between the cylinders, or if space between the cylinders should be filled in with internal deflectors to carry the air directly past the cylinders where it would have the greatest cooling effect. Dr. Lewis replied that, from the experience of one manufacturer who tried fitting the cowling between cylinders, it is believed to be much better to put the cowl completely around the engine. He does not think we shall have three-cylinder engines, and with a completely cowled five-cyl-



TESTING THE DRAG OF AN OPEN-COCKPIT FUSELAGE FITTED WITH N.A.C.A. LOW-DRAG COWL IN 20-FT. PROPELLER-RESEARCH WIND-TUNNEL AT WRIGHT FIELD

inder engine baffles could be placed between the cylinders so that all the air that goes through would do some work.

Mr. Naylor asked if the fundamental reason for the increase in airplane speed resulting from the cowling is the getting of a more forward lift on the airfoil section or the reduction of turbulence behind the engine cylinders. It is simply a case, answered Dr. Lewis, of decreasing the drag; when the Pitcairn company, for instance, installed the cowling, it faired the fuselage to meet the cowl and was surprised to find, when the plane was flown with the cowl removed, that the fairing added 5 m.p.h. to the speed. E. P. Asplundh, of Pitcairn Aircraft, volunteered the interesting information that the company's pilots reported that the airplane fitted with N.A.C.A. cowling has a much smoother "feel," the smoother airflow over the fuselage and tail surfaces being noticeable on the controls and in the lessened vibration throughout the plane. The cowling tends to concentrate the airflow around the fuselage, even though it is not flying in the direct direction of the wind.

Opportunity for further improvement in the cooling of the engine seems to be offered by the N.A.C.A.-type cowl, suggested F. G. Shoemaker, as it is evident that more finning could be added at the cylinder hot-spots and the cylinder be adequately cooled by a much lower air-blast than at present, with a gain in over-all efficiency. Dr. Lewis replied that he understands that there is a limit to finning beyond which there is no gain in cooling, but studies can be made with controlled air-cooling to design the fins so that the air will flow in a certain direction.

Navy Airplane Equipped with Handley Page Slotted Wings

Thick Ice Which Formed on the Wings When Lieutenant Harper Flew the Plane Through a 5000-Ft-Thick Cloud in Very Cold Air Last November Did Not Affect the Opening of the Slots

Lieut. C. B. Harper, U. S. N.

Who Addressed the Wednesday Night Technical Session on the Subject of Wing Slots and Their Application

Wing Slots and Tests Described

Lieutenant Harper's address dealt at some length with the causes and nature of airplane spins and their physiological effects on the pilot. The speaker then proceeded to a discussion of wing slots as a means of preventing spins and recovering from them. Several years ago the United States Navy bought the right to use the Handley Page wing slots and has experimented with them extensively. Several types of automatic slots, locking slots, interconnected slots and ailerons, and interconnected ailerons and spoilers were shown in lantern slides and described by Lieutenant Harper.

In explanation of the effectiveness of slots, it was said that when an airplane wing approaches the stalling angle it loses lift and takes on a big increase in drag because the air-stream lines are crowded together on the upper surface near the nose of the wing. With a small airfoil housed in the leading edge and pivoted so that its own air-forces cause it to move forward when the incidence of the wing approaches 10 deg., high-speed air passing through the slot forces itself over the upper surface of the mother wing and moves the burble point or area of turbulence farther back so that the wing incidence becomes nearly double that of normal stall, at the same time increasing the lift per square foot from 60 to 80 per cent. The auxiliary airfoil furnishes part of this lift and stalls a little ahead of the mother wing.

Automatic slots are used to maintain lateral stability beyond normal stall, which is of advantage in landing on airplane carriers or in restricted areas. The Navy is applying locks on automatic slots so that they will be inoperative in voluntary spins but can be unlocked at will to recover normal flight. Heavy-type Naval planes, particularly large bombers, torpedo planes and flying-boats, are being fitted with slots along the whole length of the upper wing and connected with a trailing-edge flap which is pulled down as the slot is opened. The pilot controls both the opening and closing of the slot, and as the trailing edge is pulled down it creates a fictitious angle of incidence so that advantage can be taken of the high lift of the slot at a normal landing-angle.

Use of the "spoiler" was first proposed by the Navy in 1920 to give lateral control at the stall. This is a deflector housed in the upper surface of the wing slightly back of the wing slot and hinged so that it can be raised at will by the pilot. The spoilers on the two wings are independent of each other. As either is raised, it destroys the lift due to the smooth airflow over the surface of the wing and adds drag in the direction of turn, with the result that one wing tends to drop and the other to rise, thus stopping autorotation.

Proved by Nerve-Racking Tests

Some highly dangerous and sometimes thrilling tests of wing slots in spins were narrated by the speaker, who made them, but modestly refrained from mentioning himself. With a Vought Corsair, he found that the automatic slots would open full out with

a bang in a dive at 140 m.p.h. when the control stick was jerked back with both hands. After climbing to a height of 10,000 ft. in very cold weather, and descending 5000 ft. through a cloud, during which some snow was encountered and considerable ice formed on the machine, the wing slots opened full out when the plane was brought to a stalled position at 4500 ft. altitude.

In another test that threatened a fatal ending, the slots did not operate as expected, and after landing it was found that there was considerable friction on the right slot, so that the two slots did not operate uniformly, which is necessary to balance the action.

Wing slots also enable a pilot to take off at a very high angle that would stall a plane without them and, through loss of lateral control, result in a crash. A take-off by Lieutenant Harper at about a 50-deg. angle at Philadelphia is depicted in the photograph on p. 457 of this issue.

Motion pictures of spins and tests with slotted wings added a spectacular feature to the address, and the session closed with some discussion of the subject.

Aeronautic Committee Meeting

Wichita and Cleveland Aeronautic Meetings Approved—Research and Membership Committees Authorized

THE FIRST meeting of the S.A.E. Aeronautic Committee was held Wednesday evening, April 10, being a dinner-meeting at the Book-Cadillac Hotel. In the absence of Chairman E. S. Land, of the Guggenheim Fund for the Promotion of Aeronautics, W. B. Stout, Second Vice-President of the Society, presided. Members present included Dr. Karl Arnstein, C. H. Colvin, Lieut. Carl Harper, W. L. LePage, A. L. Martinek, the Hon. W. P. MacCracken, W. C. Naylor, W. B. Stout, the Hon. Edward P. Warner and Capt. L. M. Woolson. As the personnel of the Committee is representative of aircraft interests throughout the Country, several members could not attend on account of the time and distance involved. Others present were Secretary Coker F. Clarkson, A. F. Denham, Heraclio Alfaro, Charles Heywood, A. J. Underwood and C. B. Veal.

The Aeronautic Committee is the first to function along the lines of the Society reorganization plan proposed, its primary purpose being to represent the members of the Society who are interested in aeronautics. The Committee serves as an advisory board of the Council with the authority to direct, with the approval of the Council, all aeronautical activities within the Society.

Two More Meetings Approved

The holding of two additional aeronautic meetings this year was approved, the next meeting to be in Wichita, during the time of the Wichita Aircraft Show, tentatively planned for the first week in August; and the second to be in Cleveland, Aug. 26 to 28, during the week of the National Air Races. The technical program for these meetings is being arranged by a committee under the chairmanship of Capt. E. S. Land, the other members being E. E. Aldrin, C. H. Colvin, J. C. Hunsaker, E. T. Jones, Mac Short, Chance Vought and Edward P. Warner. A list of papers being prepared for these meetings is given on p. 542.

Research and Membership Committees Authorized

At the suggestion of First Vice-President Warner of the Society, the Aeronautic Committee authorized the appointment of an Aeronautic Research Committee to cooperate with the Society Research Committee in matters of aeronautic interest. The lighting research problems now being considered by a Subdivision of the Airplane Standards Division will be carried on by this Committee.

The Committee also authorized the appointment of an Aeronautic Membership Committee to cooperate with the Society Membership Committee in interesting aeronautical engineers and executives, who are not now members, in the work of the Society. In this connection the possibility of recognizing a special S.A.E. emblem for members of the Society holding a pilot's license, issued by the Department of Commerce, was considered. The idea was not approved, as it was felt that the lack of such a pin would not be definite assurance that a man was not a pilot, the wearing of such a pin being optional.

Regarding the holding of Section aeronautic meetings, it was pointed out that it is desirable to arrange for subjects of general interest so that a large attendance of Society members shall be assured. It was thought that this policy is advisable in the case of general Section meetings, but that specialized meetings for the purpose of discussing highly technical aeronautical matters should be arranged in conjunction with such general meetings, the programs of these meetings being intended to attract only the aeronautic engineers and executives.

Wichita Aeronautic Section Favored

Organization of a Wichita Aeronautic Section of the Society was favored by the Committee on the basis that Wichita is a recognized aircraft-center and the engineers there cannot well attend meetings of any existing Section. It was felt that this matter should be brought to the attention of the aeronautic engineers in Wichita and, if there is a definite desire for such a Section, the Society should cooperate to the fullest extent. Second Vice-President Stout stated that he would be in Wichita in the near future and would be glad to discuss this with the engineers there.

The suggestion that the Society sponsor a National air-transport map was discussed at considerable length, but it was generally agreed that the development of such a map does not come within the scope of the Society's activities. Other matters considered were the testing of aircraft engines, a clearing house for engine data, aeronautic standardization, and legislation. It was the consensus of opinion that the last-named subject was entirely a matter for the Aeronautical Chamber of Commerce.

Magneto Compass and Gliding

Klemperer and Fokker Describe Motorless Flight at Joint Session with Glider Association

LANTERN slides, motion pictures and descriptions of gliding and soaring with motorless planes in Germany and America occupied most of the time and held the absorbed attention of the audience at the first technical session, on Wednesday afternoon. This was a joint session with the National Glider Association and was presided over by W. C. Naylor, Chairman.

First on the program was a paper by F. P. Wills, of the aircraft engineering department of the General Electric Co., who described and showed lantern slides of the magneto compass developed by the company he represents. This differs from the earth-inductor compass in that it employs as a field structure a bar of permalloy, which has great magnetic permeability

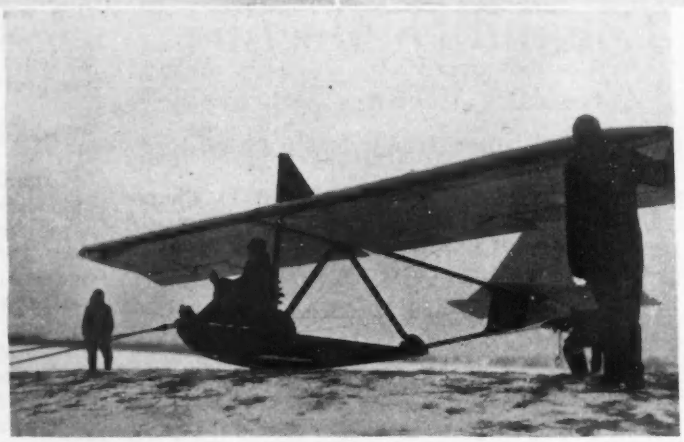
but does not retain magnetism, and is therefore very sensitive to variation in magnetic flux set up in the bar by the magnetic field of the earth as the bar is deviated from the perpendicular to the magnetic meridian.

Change in the flux is detected by means of a small rotating section of permalloy wound with a coil of wire and mounted in the middle of the divided main bar, constituting a two-pole armature spinning about a vertical axis that is fixed with relation to the aircraft. The spinning rotor cuts the flux set up by deviation of the main field from an east-west position, movement of the field bars through even ½ deg. causing a large change in value of electromotive force when using bars 12 in. in length each. A commutator of very small diameter and low peripheral speed is used. The pole pieces are changed in azimuth by means of a gear connected with the azimuth ring, instead of shifting the brushes, which are placed in such position with respect to the pole-pieces that the maximum voltage is generated when flux is induced in the bars. The sensitivity is not noticeably reduced when the brushes are shifted 10 or 20 deg. from this maximum position. No universal joint is used.

This magneto compass has emerged from the laboratory and bench-test stages and is being flight-tested in the air with the cooperation of the Army experimental station at Wright Field.

Discussion of the paper consisted mainly of notes prepared by Adolf Urfer, assistant chief engineer of the Pioneer Instrument Co., and presented by C. H. Colvin, of the same company, commenting on various comparisons given by Mr. Wills of the relative advantages and disadvantages of the earth-inductor compass and the magneto compass he described.

Turning the meeting over then to the subject of gliding, Chairman Naylor called upon Reed Landis, who spoke amusingly of his brief experiences with the sport about 15 years ago in Chicago and recently at Orient Point, Mich. The glider should offer much to engineers in the study of aerodynamics, said Mr. Landis, and also in pilot instruction. Its control is much more sensitive than that of an airplane. It offers great possibilities, too, for sport, as the cost is nominal. He hopes, however, that airplane manufacturers will give some attention to producing gliders at lower cost. The aerodynamics involved



AMELIA EARHART IN WINTER GLIDING FLIGHT AT ORIENT POINT, MICH.

The Glider Has a Single Skid and Is Started from the Top of a Hill against a Head Breeze by Men Pulling on a Pair of Rubber Ropes. When the Glider Takes the Air, the Eye at the Rope End Drops from the Hook at the Nose of the Glider and the Initiate Gets a Thrill Lasting Several Seconds, if He Is Fortunate

EDWARD S. EVANS

President of the National Glider Association, Which Held a Joint Technical Session with the Society, and a Meeting Attendant

F. P. WILLS

Engineer of the Aircraft Engineering Department, General Electric Co., Who Gave a Paper on the Magneto Compass

is very interesting, he said; it should not be too refined, or the glider will become a soarer and difficult to land.

Miss Earhart also spoke briefly, saying that her longest glider flight lasted about 36 sec., but seconds in a glider are like hours in an airplane. She would like to see as many women as men become interested in gliding, and also, as a social worker, she would like to have boys and girls of about 15 or 16 years of age take up the sport together.

Anthony Fokker was then asked to introduce Dr. Wolfgang Klemperer, who is mainly credited with the great development of interest in gliding and soaring in Germany, and is now in this Country promoting glider activities and assisting the Goodyear-Zeppelin Corp. Mr. Fokker told of seeing Dr. Klemperer make his first experiments in Germany with a glider weighing 100 lb. and beautifully streamlined, and of seeing flights there with a glider "built by a school teacher out of the scrap-heap—tin cans, beanstalks, rusty nails and old curtains."

European Glider Flights Pictured

In a long and most interesting address, illustrated with many lantern slides and a three-reel motion picture, Dr. Klemperer gave a comprehensive summary of gliding and soaring in Europe. The glider has advantages for the study of design, as it is simpler and safer than a power machine for making experiments and is also valuable for gaining experience in landing. The glider always takes off to make an emergency landing. Tailless and tandem-wing planes and slotted wings were used in gliding before they became practical on power planes.

Every one wonders how a motorless plane can stay aloft, said the speaker, who then explained that the principle of static flight is simple; currents of air on the windward side of a hill, along the seashore or at the edge of a wood rise faster than the glider descends by force of gravity. By skirting along the edges of a range of hills and making figure 8's, the pilot can soar sometimes for hours, and cover considerable distances.

Duration, Distance and Speed Records

The duration record is now over 14 hr., the distance record over 45 miles, and the maximum speed between 40 and 45 m.p.h., mostly laterally to the wind. There are places in America, said Dr. Klemperer, where it is feasible to make a glider flight of 100 miles, and he believes a glider flight from Los Angeles to San Francisco is by no means impossible.

Clouds and cloud formation indicate ascending air-currents, and "cloud hopping" is the aim of gliding experts. Intricate charts of flight courses from designated starting points to designated destinations and return were shown, as were also slides of flights to descents within a few feet of designated landing-marks.

Council Approves Constitutional Amendment

CONSTITUTIONAL amendments made necessary to put into effect the Society reorganization plan, as reported in the December, 1928, and February, 1929, issues of THE JOURNAL, were discussed by the Council of the Society at a session held in Detroit on April 9.

Formal notice of the proposed changes, together with copies of the amendments, were mailed to the voting members of the Society in April.

The amendment of Section B 24 of the Constitution, to provide that the Nominating Committee shall nominate officers at the Annual Meeting instead of the Semi-Annual Meeting as heretofore, was approved, the amendment to take effect immediately, as provided in Section C 57.

This amendment reads as follows:

> B24. It shall be the duty of the Nominating Committee to organize at the Annual Meeting of the Society and to send to the Secretary, on or before Oct. 1, the names of consenting nominees for the elective offices next falling vacant under the Constitution. The report of the Committee shall be printed in the next current publication of the Society.

Discontinuance of the sending of letter-ballots on standardization recommendations was voted by the Council, with the object of expediting the adoption and publication of standards and recommended practices by the elimination of this step which is no longer regarded as necessary. Further mention of this subject is made in the Standardization Activities department in this issue of THE JOURNAL.

Student-Branch Committee Confirmed

Appointment of a Student-Branch Committee was approved and the appointments as follows were confirmed:

F. C. Hecox, *Chairman*

P. Altman	F. S. Linsenmeyer
V. G. Apple	E. F. Lowe
L. V. Cram	K. W. Stinson
Dean Fales	G. S. Whitham

John Younger

The appointment of Captain E. S. Land as a member of the Wright Brothers Medal Board of Award for the term expiring in 1931, was also approved and confirmed.

Members of the Council attending the session were: President Strickland, First Vice-President Warner, Past-President Wall; Second Vice-Presidents Berry, Kliesrath and Sawyer; and Councilors Fishleigh, Parker and White.

Finances and Memberships

A financial statement as of Feb. 28, 1929, was submitted and discussed. This statement showed a net balance of assets over liabilities of $204,058.16, this being $1,356.85 more than the corresponding figure on the same day of 1928. Gross income of the Society for the first five months of the fiscal year amounted to $152,043.63, the operating expense being $158,515.39. The income for the month of February was $33,391.03 and the operating expense during the same month was $31,414.31.

The election of 162 members, 15 grade transfers, 4 resignations, 16 reinstatements, and 6 reapprovals, on which the Council had acted by mail vote, were confirmed. Thirty-five additional applications for membership were approved, and also 13 transfers in membership grade, and 8 reinstatements. The change in name of an Affiliate Member and the change in the representation of another Affiliate Member were approved. Three applications were reapproved.

It was reported that 5702 Members had paid Society dues as of April 1, 1929, as compared with 5364 on the same date of last year; also that 3862 Members had paid Section dues as compared with 3362 as of April 1, 1928.

Ladies' Night at Cleveland

Kettering Speaks on Engineering Education and Detroit High Hats Play for Dancing at Banner Section Meeting

AFTER eight years of being snubbed, the ladies of Cleveland were invited to the meeting of the Cleveland Section at the Hotel Cleveland, April 17, to enjoy an excellent vaudeville program during dinner, to listen to a characteristic talk by C. F. Kettering, and to participate in dancing to the syncopation of the High Hat Orchestra of the Detroit Section, famed as the highest salaried orchestra in existence. Guests to the number of 320 cheered the speaker, the music, and all the guests at the head table, who were introduced in turn by Chairman Ferdinand Jehle; but all were quiet for a moment when the Chairman called for a silent toast in memory of William C. Naylor.

Dinosaur Provides a Perspective

To establish a perspective, Mr. Kettering expressed interest in the recent finding of the skeleton of a dinosaur which has been buried in the Gobi Desert for 80 million years. Last summer the head of the astronomical department of Harvard University produced a picture of a spiral nebula, the light for producing which left its source 20 million years before that dinosaur was born. The engineers were invited to calculate the number of miles to the nebula, and how large a gasoline tank would be required to drive out there some Sunday afternoon.

Engineering education fails to prepare the student for his real work because it does not teach him enough of economics and psychology, according to Mr. Kettering. As a result, the young engineer cannot sell his ideas, and he becomes discouraged and drifts into other lines of work where the rewards seem to be greater and more immediate. For instance, only 6 out of 37 graduates in electrical engineering in one single class were found to be practising electrical engineering 10 years after graduation. Engineering graduates are earning small salaries, and still there is a feeling of a lack of engineers all over the Country.

To Fit Students into Industry

To fit engineering graduates into industry, put them on a job that is similar to what they were studying in college, advised the speaker, and give them a chance to become acclimated to industry and assume a more important position. Answering questions in a final examination is not sufficient preparation to meet the many limitations of practical problems.

The engineer needs patience to present an idea again and again. After four years' trying, it may be accepted. During the last 50 years we have learned how to measure things and how to calculate, but many engineers have not yet learned to use their imagination. We find in industry a question as to what the future demand will be, and the engineer should have enough imagination to see that the things of tomor-

THE DETROIT HIGH HATS WHO ENTERTAINED THE CLEVELAND SECTION AT ITS RECENT MEETING

Left to Right—"Eddie" Griffith, D. E. Anderson, H. Albert Hausen, Fred A. Cornell, G. A. Drew, Charles A. Pokorny, John R. Bartholomew and "Phil" Overman

row will be different from those of today.

Bankers, said Mr. Kettering, are interested in the engineer as never before, because they say that he is upsetting the stability of business. The whole object of research is to keep everyone reasonably dissatisfied with what he has in order to keep the factory busy making new things.

If a new car worth $2,000 were hermetically sealed in a glass case, its value would decrease say 10 per cent per year. The job of the engineer is to put back into each new model the 10 per cent that has been lost by depreciation. He must be able to read ahead several years down the road to know what to develop.

Should Question Handbook Data

Handbook information can never be taken as final. A few years ago, soft Norway iron was universally regarded as the best material for making magnets; any alloy made it poorer. Yet patient experimenting finally showed that a 71-per cent nickel alloy has 110 times the permeability of iron, and the result is that we now have transatlantic cables that are eight or ten times as fast as any that have heretofore been made.

Tungsten-carbide cutting-tools may cause a revolution in manufacturing, as to both cutting speed and range of materials that can be machined. A man directly connected with its development told Mr. Kettering that the material is nearly as hard as a diamond and "that is about as far as we can ever hope to go." But Mr. Kettering does not recognize the hardest material in nature as an ultimate limit of hardness.

Mr. Kettering, who has been an aviation enthusiast and pilot for 16 years or more, believes that many aviation problems must be solved before the aeronautic industry can come into its own as it should. The radio will help with some of these.

Although it is said that "Any man who is thinking of tomorrow is peculiar today," it is necessary for everyone to be looking forward to and working for the future. "The only park benches along the road to progress are in front of the undertaker's office."

Economics of Powerplant Design

Taub Reveals the Engineering Secrets of the Chevrolet Six to the Metropolitan Section

About 150 members and guests of the Metropolitan Section gathered in the Colonial Room of the Park Central Hotel Thursday, April 18, to hear and discuss the paper given by Alex Taub, research engineer of the Chevrolet Motor Co., on the Economics of the Chevrolet Powerplant. Vice-Chairman Round, who presided at the meeting, expressed regret that the hotel had not provided for many more dinner guests than had made reservations, as a number of the later arrivals were disappointed.

Mr. Taub's paper explained rather fully the engineering considerations leading to the design of the present Chevrolet engine. Members who discussed the paper commended the amount and kind of information given, although not all of them agreed with the conclusions. T. J. Lítle, past-president of the Society, for instance, sent a telegram in which he expressed his appreciation of the paper and his belief in design tendencies different from those exemplified in the engine under discussion, as might be expected from the characteristics of the engines he himself designs.

Why Six Cylinders Are Needed

Once the manufacturers of very low-priced cars depended upon price entirely to win the approval of the buyer, according to Mr. Taub, but now the powerplant of a car in that class must give a large measure of utility per dollar to both the user and the manufacturer and must anticipate and help to develop the trend of demand. The sales organization helps to present the buyers' views, and the manufacturing department contributes features to facilitate production.

More weight is being added to cars, partly for the sake of appearance. This cannot be done without a proportional or greater increase in power, because the cost of the heavier car is greater and the public will not accept the more expensive car without an increase in ability. The four-cylinder engine has reached the limit of acceptable size because of roughness, according to the author, and six cylinders therefore are necessary. Elimination of the secondary vibration of the four-cylinder engine contributes to the durability of the other chassis parts. An increase in piston displacement was chosen rather than other methods for obtaining more power, because such an increase is permanent and does not depend upon the care given by the user and low speed contributes to durability.

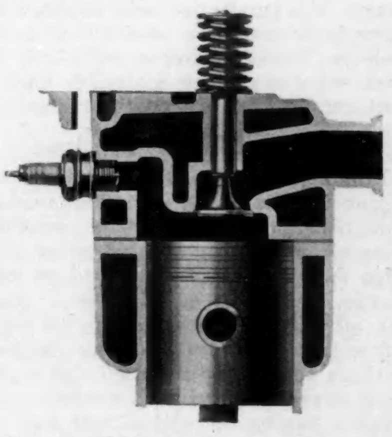


Fig. 1—Combustion-Chamber of Chevrolet Engine

Simple Crankshaft and Lubrication

Three-bearing crankshafts for cars of this class were defended vigorously by Mr. Taub. The middle bearing divides the engine into two groups which are in static balance, thus relieving the bearings of twisting tendencies that are present in four-bearing and seven-bearing designs unless neutralized by counterbalances. Because of the short stroke and absence of counterbalances, the torsional-vibration period can be made very high, thus placing beyond the driving range one of the difficulties of six-cylinder engines. Analysis of the fiber stresses at different parts of the shaft, given with the paper by curves, shows that the factor of safety is always greater than five. Manufacturing advantages of the design are that the crankshaft can be forged directly with the crankpins in index, and is very stiff for rapid and accurate machining.

Reasons which led to adoption of the splash-lubrication system were given. This system includes pockets over the main bearings in which an oil level is maintained above a standpipe that leaves a sediment chamber. Much study was given to the oil scoops on the connecting-rods, including stroboscopic studies of a cutaway bearing showing that, in this particular design, the oil is thrown into the bearing twice during each revolution of the crankshaft. Pressure is maintained at the camshaft bearings and the oil is delivered positively through the rocker-shaft of the overhead valves to the valve mechanism.

Valves and Combustion-Chamber

Overhead valves do not give the cheapest construction, but Mr. Taub considers that they represent a high utility per dollar. Such a design can be produced by an organization that is accustomed to it at a cost that is reasonable, in view of its volumetric efficiency and accessibility. The chief difficulty is to overcome noise. In the design under discussion, the inertia has been reduced and the cam outline im-

proved by the ratio of the valve-rocker; and difference in expansion between the exhaust and the inlet parts has been controlled by a difference in the length of the valve guides. The push-rod expansion is regulated by the amount of ventilation, which controls the temperature, and the cylinder-block expansion is regulated by the length of the water-jacket. The result is reported in a maximum variation of 0.003 in. in push-rod clearance during a series of tests at various speeds and with various water temperatures.

The difficulty in following the advance made in combustion-chamber design of L-head engines has been met in this design by an L-shaped upward extension at one side of the valves and an area of close clearance at the other side. This close clearance over 16 per cent of the piston area controls the temperature of the last gas to burn, as in L-head engines. The spark-plug is located in the extension. A section of this chamber is shown in Fig. 1.

Drilled Holes Hard to Clean

Questions asked and Mr. Taub's answers constituted most of the discussion. This was led by F. H. Dutcher, of the mechanical engineering department of Columbia University, who remarked that the tendency of the times seems to be for more driver comfort at the expense of efficiency. He asked why pressure lubrication was not used. Mr. Taub countered with, "What do you want for 10 cents?" and said that pressure lubrication for engines made in the largest quantities awaits an automatic and positive method of cleaning out the holes drilled in the crankshaft. Under present conditions, trouble could be expected from imperfect cleaning, while bearing life proves that splash lubrication is positive and effective.

Credit was given to H. M. Crane for his help in the general design of the engine and to R. N. Janeway for his contribution to the design of the combustion-chamber.

In reply to a question from Herbert Chase, Mr. Taub said that steam-cooling would eliminate thermostats and other complications but will not meet popular approval until a satisfactory condenser has been developed to dispose of the steam that appears as soon as the car is stopped.

The piston-pin in clamped in the connecting-rod to avoid difficulty in maintaining the clearance in a bushing at the end of the rod. It was found impossible to provide clearance enough to allow for expansion of the pin, when hot, without causing a knock that will increase the clearance still further. The piston-pins are chromium-plated. Cast-iron pistons are used, although aluminum pistons would be needed for an engine having higher speed and higher compression.

Vice-Chairman Round expressed his belief, as a lubrication engineer, in the low-speed engine and splash lubrication. He believes oil troubles are less with this design, but the oil scoops must be well designed to avoid over-oiling. Stroboscopic studies of one engine show that the oil is splashed by one scoop to a position where the crank-arm of the adjacent cylinder will throw it directly into the cylinder bore.

Diesel-Engine Meeting

Light High-Speed Engines Described by Jackson and Cummins at New England Meeting

HIGH-SPEED light-weight Diesel engines held the floor at the New England Section meeting in the Engineers Club in Boston on April 17. Section-Chairman Knox T. Brown presided over an attendance of 132 men who came to hear papers by Philip B. Jackson, of the Aluminum Co. of America, and C. L. Cummins, of the Cummins Engine Co.

Mr. Jackson's paper dealt with the application of aluminum alloys to Diesel engines, particularly their use for lightening the reciprocating parts. He gave also a demonstration showing the relative rigidity of three cantilever beams, one of steel, one having the same thickness of aluminum, and a thicker aluminum beam of the same weight as the steel beam.

In introducing his paper, Mr. Cummins said that the common use of Diesel engines for motor-cars is not near. Eventually it will come, but there is no economic need for it now; and the Diesel engine is not ready to meet the demand for a flexible engine that cannot be heard, felt or smelled.

High-Speed Engine Problems

Problems of the high-speed Diesel engine were listed by Mr. Cummins as (*a*) obtaining the highest possible volumetric efficiency; (*b*) securing uniform distribution of fuel through the charge, by means of turbulence; and (*c*) advance preparation of the fuel before injection. He considers the last of these the most important for high-speed operation, and that air injection possibly causes the globules of fuel to be frozen at the time of injection, resulting in a time lag that is incompatible with high speed.

Mr. Cummins then described the particular injection system of the Cummins engine, in which the fuel is drawn first into an annular space near the injection nozzle, where it remains to be heated during one cycle of the engine. It is then drawn into a small chamber, together with compressed charge from the cylinder sufficient to vaporize it, and ejected from this chamber into the cylinder at the correct time for combustion. This device was described in detail by Mr. Cummins in a previous paper, which was printed in THE JOURNAL for October, 1927, p. 388.

The Cummins method of injection has been used satisfactorily in engines ranging in size from 4½ x 6 in. to 21 x 21 in.

A more recent development of his engine includes a bottle-like chamber in the top of the piston, comprising 3 to 5 per cent of the compression space of the cylinder and having an opening directly opposite the fuel nozzle. This bottle is filled with air that is compressed during the compression stroke, and during the expansion stroke it discharges a stream of heated air through the zone of rich mixture around the injection nozzle, thus making combustion complete and avoiding carbonization of the nozzle. This construction was illustrated in connection with a Metropolitan Section meeting reported in the S.A.E. JOURNAL for April, 1928, p. 497.

Service Conditions Should Govern Use

Regarding the possibilities and limitations of the small Diesel engine Mr. Cummins said that their promiscuous use should be discouraged where service conditions are not good enough and where the gain in fuel economy, compared with a gasoline engine, will not justify the additional cost. Where a small Diesel engine can be properly applied and serviced and operated at full throttle, it can produce power as cheaply as the largest powerplant; electricity can be produced with a 5-kw. outfit for approximately ½ cent per kw.

Replying to a question about lubrication, Mr. Cummins expressed a preference for oil having a somewhat higher flash-point than oil that is commonly used in gasoline engines. It is common for automobile oils to flash at about 350 deg. fahr., and he prefers an oil that will go to 450 or 500 deg. before flashing. Such oils can be obtained from various manufacturers. Cylinder-walls are subject to higher temperature in a Diesel engine than in an Otto-cycle engine, and a low-flash-point oil sometimes causes the engine to give out a blue smoke.

Pittsburgh Section Proposed

AT a luncheon-conference on April 19 at the William Penn Hotel in Pittsburgh, an Organization Committee consisting of N. G. Bjorck, chairman;

B. H. Eaton, C. F. Kells, C. J. Livingstone, C. R. Noll and James W. Trimmer was appointed to organize a Pittsburgh Section of the Society, with the understanding that the first meeting would be held early next autumn.

The luncheon-conference was held at the suggestion of Mr. Bjorck, who feels that there is sufficient Society interest in Pittsburgh to support local activities. It was called at short notice, most of the members in Pittsburgh being advised by telephone on the day of the meeting.

It was found to be the consensus of opinion that, with the cooperation of Carnegie Institute and Mellon Institute, there was every reason to believe that the more than 80 local S.A.E. members would be glad to support local technical and social activities. It was reported that an analysis of the membership in Pittsburgh showed that virtually every phase of automotive engineering is represented. It was also pointed out that almost every member in the city should be able to interest non-members in the Society if local activities were inaugurated.

It was generally agreed that the Committee should meet several times during the summer to assure a successful initial meeting in October, which would be open to members and nonmembers alike.

Members attending the conference were:

N. G. Bjorck, Lange Motor Truck Co.
C. S. Burlingham, West Penn Railways Co.
B. H. Eaton, Bell Telephone Co. of Pennsylvania.
Murray Fahnestock, *Ford Dealer and Service Field*
D. L. Hubbard, Edgewater Steel Co.
C. F. Kells, West Penn. Electric Co.
C. J. Livingstone, Mellon Institute of Industrial Research
Edward A. Malin, Pittsburgh Parts Mfg. Co.
A. C. Mathieson, Westinghouse Air Brake Co.
C. R. Noll, Gulf Refining Co.
J. M. Orr, Equitable Auto Co.
A. D. Tiel, Autocar Sales & Service Co.
J. W. Trimmer, Carnegie Institute of Technology
Oscar R. Wikander, Edgewater Steel Co.
Charles Heywood, Society of Automotive Engineers.

Lamps and Lamp Service

Chicago Section Told About Miniature Lamp Making and Adequate Headlighting Without Glare

AUTOMOTIVE head-lamps were the subject of two papers read on April 2 at the monthly meeting of the Chicago Section, held at the City Club before an attendance of 40 members. Chairman J. W. Tierney, of the Electric Storage Battery Co., commented upon the good work of the Section's Membership Committee, which, under the chairmanship of Clarence H. Jorgenson, of the Dole Valve Co., had brought the Section total to 343, or 47 members more than that of the Cleveland Section, which had led Chicago at the beginning of the year.

Chairman Tierney then invited the members to consider the possibility of making the May meeting an aviation event, with the members starting at the Municipal Airport and, after a half-hour's flight in formation, riding in motor-coaches to the place of the dinner and meeting. He expressed his conviction that a formation flight in tri-motored airplanes would result in not a little publicity for the Section, and that it would be worth "digging into the Section funds a little" to render such a meeting possible.

Walter Martins, of the Automotive Service Co. and Chairman of the Section Nominating Committee, reported that the following members had been recommended for nomination as officers: for Chairman, D. P. Barnard, 4th, of the Standard Oil Co. of Indiana; Vice-Chairman, George A. Buckbee, of the Hyatt Roller Bearing Co.; Secretary, John O. Eisinger, of the Standard Oil Co. of Indiana; Treasurer, Elliott W. Stewart, of the William D. Gibson Co.

Carlson Talks on Miniature Lamps

The first speaker was R. E. Carlson, of the Westinghouse Lamp Co., whose paper dealt with The Incandescent Lamp for Automotive Lighting. He stated that standard lamps used on present-day motor-cars are of the gas-filled tungsten-filament type, and accounted for more than one-half of the 250,000,000 miniature lamps sold in the United States during 1928. The production of these lamps is now on a manually-supervised automatic-machine basis. An elaborate system of rigid inspection has been designed to assure a high-quality Mazda production, he said.

Mr. Carlson spoke of the far-reaching effects of the simplification program that has been carried out in the lamp field. More than 24,000,000 motor-vehicles are now served regularly, and 90 per cent of their lamp needs are taken care of by 11 or 12 lamp sizes, as a result of standardization. Incidentally, quantity production of a few types has reduced the retail price so decidedly that today it is only about 60 per cent of what it was in 1920. He then showed curves illustrating different characteristics of tungsten-filament lamps, such as varying energy and radiation output, and the relation of voltage to candlepower and lamp life.

While manufacturers are doing their best to produce uniform and high-quality lamps, the degree of satisfactory performance obtainable from the product depends largely upon the conditions under which it is made to function, said Mr. Carlson. Mentioning several present tendencies in the automotive lighting-field, he remarked that perhaps the greatest forward step made last year was the adoption of fixed-focus head-lamps by several car manufacturers.

Lehnen Discusses Good Headlighting

The Wisconsin Certified Adjusting Service was the topic treated of by E. J. Lehnen, chief engineer of Day-Nite, Inc., of Waukesha, Wis., who addressed the meeting in view of the inability of Chester S. Ricker, president of the company, to attend. Mr. Lehnen said that improper adjustment and other factors often cut down the usefulness of a head-lamp to its owner by 50 per cent. Another circumstance that renders night driving unnecessarily difficult and hazardous is the requirement, still maintained in several States, of a driver dimming his head-lamps when approaching another car. This method is distinctly opposed to what might be called the controlled bright-light system. Continuing, Mr. Lehnen said:

In Wisconsin we believe in this idea, and incidentally it is prevalent in practically every State at this time, and growing daily. The idea is to have your lights so adjusted that you get the greatest efficiency from them for yourself. Have them adjusted so that you personally get good, reasonable and adequate light down the roadway and you have automatically taken care of the other fellow to a large extent. You can take an extremely selfish attitude, because, if you use your light to the greatest advantage for yourself, it means that you have taken away a great deal of the wasted, stray glare light from his eyes and put it down on the road where it belongs.

In other words, in Wisconsin we look at the lighting situation rather from the glare-penetration angle. That is perhaps a somewhat new thought, at least the use of that particular term is, although the idea may not be so new. By glare penetration I mean directing as much of the available light from your lamps as is possible and practicable down on the roadway, so that to a large extent you overcome and offset the glare from the oncoming motorist's car.

We all realize that the Society and other organizations have done much valuable work and produced some great improvements in head-lamps, but is it not equally important to set standards which provide for reasonable and adequate illumination on the highways; that is, providing for illumination under conditions of actual use rather than mere laboratory specifications? Because lamps that are adjusted according to laboratory specifications may still provide inadequate illumination on the highways after

they have been in use for a time, due to many circumstances, such as low voltage, dirty or tarnished reflectors, twisted lenses, and all the other things that cause our common lighting difficulties.

Quoting from figures compiled by the National Safety Council, the speaker explained that 64 per cent of the annual 800,000 automobile accidents in this Country occur between 5 and 12 p. m. This fact, he said, indicates the relation between inadequate and defective head-lamps and night accidents.

Wisconsin Anti-Glare System

As part of an attempt to solve the problem of glare penetration, tests made by C. R. Granberry, of the University of Texas, were cited by Mr. Lehnen, who introduced a number of slides showing, by plotted graphs, the results of comparative-visibility tests carried out with a number of individuals under divers conditions. The speaker stated that plenty of controlled light directed down on the highway offsets to a large extent the objectionable glare created by the head-lamps of approaching cars. The Wisconsin system of glare-correction aims to give the motorist a good driving-light rather than prevent his use of a glaring light. This system was developed to fit the standards set by the State Industrial Commission to realize adequate road illumination while at the same time minimizing head-lamp glare. The adjusting service makes a photometric check on the cars in service on the road, to determine whether they meet the specifications laid down by the Commission.

At present, tests are being made over a 25-ft. distance, and the lamps of many thousands of Wisconsin cars were examined and adjusted last year. About 90 per cent of the cars were brought in by choice of the owners, and 10 per cent as a result of orders issued by the authorities. In most instances, the lighting could be greatly improved simply by adjusting the head-lamps, and complete lamp replacement was necessary with only 1 per cent of the cars, though there was a good deal of parts replacement.

Main Points in Discussion

In the course of the discussion, E. A. Sipp, of the Pyle-National Co., asked Mr. Carlson regarding the average decrease in percentage of mean spherical candlepower for a 1-per cent voltage drop or a 1-volt drop. Mr. Carlson replied that a 10-per cent decrease in voltage would reduce the candlepower from a basic 100 per cent down to 70, a 3-to-1 ratio in percentage.

Responding to a question about permanent-focus lamps, he said that such lamps, now used on the Chevrolet and Whippet cars, make possible the replacement of bulbs without distorting the beam. He expressed the opinion that, although fixed-focus lamps may prove satisfactory, they will, even as other lamp equipment, require service, although the beam may not require aiming or focusing.

A query by Walter Martins as to how frequently head-lamp trouble is due to poor ground-connection or to the single-wire system, brought the statement from Mr. Lehnen that the importance of these factors led his organization to devise a unit that contains a voltmeter and can be plugged right into the lamp. The bulb is removed and placed in another socket, which is an integral part of the unit, so the lighting voltage remains constant. Attached to this unit is a separate lead which is slipped down the framework to show just what the loss in voltage is, due to the connection from the point where the battery is grounded up to the lamp. A great deal of difficulty occurs at this very point, said Mr. Lehnen, and the seriousness of this trouble is readily appreciated in the light of Mr. Carlson's remarks, quoted herein, that indicate that a drop in voltage is accompanied by a very much greater drop in candlepower.

Joint S.A.E. Student Meeting

More than 400 Students Attend Conference Sponsored by Detroit Section at Research Laboratories

MORE than 400 S.A.E. enrolled students from Ohio State University, the University of Michigan, the General Motors Institute of Technology and the University of Detroit attended a Student Branch meeting, sponsored by the Detroit Section, at the General Motors Corp. Research Laboratories on April 22, and heard a very interesting program arranged by Chairman Lemon of the Detroit Section, who presided.

Among the speakers were F. C. Hecox, of the Cadillac Motor Car Co., chairman of the recently appointed Student Branch Committee of the Society; Prof. F. J. Linsenmeyer, of the University of Detroit; Prof. W. E. Lay, associate professor of automotive engineering at the University of Michigan; and President W. R. Strickland, who gave the students a brief welcome and made a few remarks on the purposes of the S.A.E. and its student enrollment.

Walter T. Fishleigh, of the Ford Motor Co. and past chairman of the Detroit Section, gave a most interesting impromptu talk on what constitutes an "engineer" today. Prof. John Younger, of Ohio State University, and Dr. F. O. Clements, technical director of the General Motors Corp. Research Laboratories, entertained the groups with a few short and snappy remarks of wisdom and humor. Mr. Lemon then introduced H. C. Mougey, head of the chemical research department of the General Motors Corp. Research Laboratories, who delivered the principal address of the evening, on Lubricants and Fuels.

Fascinated by Inspection Trip

Following the speaking program, the students were conducted in groups of about 20 through the major proportion of the five floors of the new Research Laboratories. This inspection trip proved so fascinating to the students that after 11:30 p.m. it was necessary to send the guides through the huge building to reassemble the little groups scattered here and there on the several floors, so eager were the boys to see more of the interesting establishment.

A meeting of the S.A.E. Student Branch Committee, with F. C. Hecox presiding, was held informally after the meeting proper and before the trip of inspection.

Officers of the Student Branches of the General Motors Institute of Technology, the University of Detroit and Ohio State University joined in a discussion of tentative plans and programs for future activities of the National Committee and Student Branches in general.

Coach Maintenance Sketched for Northwest Section

FIFTY members of the Northwest Section met at the New Heathman Hotel, Portland, Ore., to attend a dinner in the Aeronautic Club rooms followed by a meeting at which Section Chairman A. M. Jones, of the Willis-Jones Machinery Co., presided. Several new applications for membership were received at the meeting, and the Section accepted an invitation from Tacoma, Wash., to hold its September meeting there.

Carroll C. Humber presented a paper on Motorcoach Maintenance, based on his suburban operating experience with the Longview Public Service Co. since its service started with six coaches in 1922. At first the operation was over gravel roads which became almost impassable after a rain, and much trouble was experienced with broken chassis parts and worn brakes and bearings.

In 1923, the fleet had increased to more than 150 units, including tractors, cranes and other engine-powered equipment, and an inspection system was instituted. Some improvement was immediately apparent, but the system was

further improved by changing it to a mileage basis, with inspection-sheets prepared for each type of vehicle.

Another improvement was made by discarding the system of complete overhauling for one whereby any part is replaced at the time of inspection if it is thought to be unsuitable for continuous satisfactory service until the next periodic inspection. This caused an immediate drop of 2 cents per mile in maintenance cost and eliminated uncertainty as to failures. The inspection involves approximately 55 hr. of labor for each 100,000 miles, at a cost of about $41.25.

Upkeep and Consumption Reduced

Mr. Humber said that each operation with which he is familiar would require a different system of inspection and maintenance, which should be worked out by the fleet superintendent. In his work, many of the **units on** trucks traversing gravel roads are inspected twice as often as those which travel on pavement. During the first years, when considerable of the work was hard and required much use of the lower gears, there was excessive engine-bearing wear. Different brands of oil gave little relief, but the substitution of aluminum pistons cured the trouble and increased from 50,000 to 150,000 miles the mileage before engine-blocks required reboring.

Gasoline and oil mileage is carefully watched and posted each day; if the average drops as much as 4 per cent during any month, the cause is investigated. It is found that any need for valve-grinding or cylinder repairs is indicated in this way. Sometimes the cause is found in the ignition or the carbureter.

The entire cost of operation has been reduced from 26 cents per mile in 1923 to 16 cents in 1928. During the three-year period ended last December, the cost of gasoline, oils, and labor of cleaning and greasing was 18.6 per cent of the total cost, and the cost of maintenance materials and labor was 9.7 per cent. Average mileages for fuel and oil were 8.2 miles per gallon and 65 miles per quart.

Special Transmissions Discussed

Synchronized, Four-Speed, and Seven-Speed Types and Maintenance Considered in Los Angeles

FOUR PAPERS dealing with transmissions were delivered before 70 members who attended the regular monthly meeting of the Southern California Section on April 12, at the Los Angeles City Club. Section Chairman Eustace B. Moore, of the Los Angeles Automotive Works, announced that consideration was being given to the possibility of holding the Section's future meetings on the first Friday of each month instead of on the second, as is the present practice. The change would space the Northern and the Southern California Section meetings a week apart and should help to increase the attendance at both.

Ethelbert Favary, of the Moreland Motor Truck Co., then addressed the meeting, emphasizing the importance of a general increase of effort toward greater Section membership. He also suggested the forming of an aeronautical division in Southern California, to interest and bring together the aircraft men in that territory. The next meeting of the Section will be on May 10 and will be an aeronautic meeting, with a paper on Small Aircraft Engines, by Mr. Tilley, chief engineer of the Kinner Airplane & Motor Co., and probably one or more other papers.

Three Transmission Systems Explained

The first paper at the April meeting, by Jack Frost, of the Don Lee Co., was descriptive of the synchronized transmission now used in the Cadillac cars. The construction of this gearset was shown by slides, and the underlying principle, synchronization of the intermediate gears on main and jack shafts, which are always in mesh, was explained by the speaker, who paid special attention to the process of gear-shifting involved in the operation of this transmission.

Harry H. Jones, service manager of the Graham-Paige Co. of Southern California, spoke on the four-speed transmission developed by the Graham-Paige Motor Corp., stating that, by combining this gearset with a rear axle geared higher than usual, high car-speed at low engine-speed has been rendered possible, together with rapid pick-up and good hill-climbing ability. Direct drive is attained in fourth speed, while third speed is a semi-direct drive through quiet internal gears, with a ratio slightly below the normal direct gear in three-speed cars. The ratio in fourth being 3.6 to 1, said Mr. Jones, the Graham-Paige engine turns about as fast when the car moves at 60 m.p.h. as does the engine of the average three-speed car at 48 m.p.h. He emphasized the low depreciation and maintenance cost conditioned upon this comparatively slow engine-speed. Two motion-picture films showing the action of the transmission and illustrating the points made by the speaker were shown.

The Brown-Lipe seven-speed transmission was described by John Wiggers, chief engineer of the Moreland Motor Truck Co., who showed by means of diagrams that it is similar in design to the four-speed gearset. The seven-speed design has two countershafts operating at different speeds, giving a high range and a low range. Accordingly, the principal advantage of the seven-speed transmission is a greater range of speeds than the three-speed or the four-speed set affords. Moreover, it provides an overdrive that is 30 per cent faster than direct drive. Comparative performances of four-speed and seven-speed transmissions were shown by Mr. Wiggers by means of tabulations and curves.

Troubles and Remedies Discussed

Transmission maintenance was then discussed by Robert N. Reinhard, of the California Co-operative Creamery Co. His paper listed the more frequent troubles experienced by operators of automotive equipment such as his firm uses, some measures used to prevent these troubles, and the methods followed in repairing transmissions in the company's vehicles.

In the course of the discussion, J. W. Sinclair, of the Union Oil Co., said that in vehicles operated by the oil company excessive engine-bearing trouble had developed on account of the wide spread between third and fourth speeds, which necessitates racing the engine before shifting into fourth speed. Adjustment of the ratio between third and fourth speeds, he said, reduced considerably the troubles from this source.

Vibration in Motor-Cars

Lítle Outlines at Philadelphia the Causes and Cures for Many Vibrations and Sounds

AT THE OPENING of the Pennsylvania Section meeting in Philadelphia, April 10, it was announced that J. H. Geisse, who had been nominated to be the next Chairman of the Section, has left Philadelphia. Accordingly, it was necessary to make a substitute nomination by means of a petition signed by 12 members of the Section. In this way, "Cap" Dalton Risley, Jr., of the Craveroiler Co. of America, was placed in nomination.

Chairman Adolph Gelpke, who presided, announced that the May meeting of the Section would be on the subjects of airport planning and airport opera-

tion, with papers by Francis Kelly and E. A. Jackson. He then introduced T. J. Lítle, Jr., Past President of the Society, and chief engineer of the Marmon Motor Car Co., who read a paper on Vibration in Motor-Vehicles.

Torsional Vibration Overcome

Dividing his subject into the elimination or limitation of vibration at its source and the control or absorption of vibration that cannot be eliminated, Mr. Lítle began with the engine and pursued vibration through the various parts of the car and out through the body-panels and the roof. Vibration in the four-cylinder engine no longer interests many car designers, he said. Secondary vibrations are eliminated in the six-cylinder and eight-cylinder in-line designs, but torsional vibration of the crankshaft is a problem. This has been solved successfully by the Lanchester dampener, and more recently in the Marmon engines by a light disc attached to the front end of the crankshaft by means of rubber. Heavier flywheels could be designed to eliminate the worst vibration period, but were found to be ineffective at other periods. The light disc is found to respond to the different periods, and the internal friction of the rubber mounting damps the vibration. A similar damping disc incorporated in the clutch has proved beneficial.

After a brief consideration of vibrations and noises in the transmission and propeller-shaft, Mr. Lítle said that non-skid tires sometimes cause a vibration that is very difficult to distinguish from gear noise in the rear axle. At one time a car manufacturer rejected a large number of axles because of noise which was finally traced to the tires.

Many Uses for Rubber

Engine mountings have been the subject of much study to prevent the transmission of engine vibrations to the frame. Of the various forms tried, rubber mountings seem to be the most successful, and Mr. Lítle predicts much greater use of rubber to prevent the transmission of vibrations throughout the car. The properties of rubber are not well understood; one of its peculiar features is that manipulation, if not excessive, increases its life.

Rubber has many possibilities for the elimination of vibrations, and rubber air-bags are said to have been used successfully in Germany as a substitute for steel chassis-springs. A rubber mounting of the fan has been found to make that unit quieter and also to function as a vibration damper for the engine. Tubular-rubber drives are used for engine accessories, and there is an increasing interest in rubber universal-joints. Rubber-insulated joints and mountings have been used on steering-gears, and there is a fertile field for the inventor in the elimination of the smaller mechanical joints in the braking system and control rods.

Lighter construction, following the lead of airplane design, is recommended by Mr. Lítle as a method of reducing vibration. If the total weight of the car is reduced in this way, a smaller engine will drive it, and the smaller engine will produce less vibration. Aluminum at lower cost is one of the means to accomplish this, and Mr. Lítle laments that the development of Muscle Shoals, which might produce aluminum at low cost, has been halted.

Spring Connecting-Rods Proposed

Several inventors were said by Mr. Lítle to be working on elastic connecting-rods, to reduce vibration from engine explosions at its source. The transmission of vibration from the engine to the frame and from the frame to the body can be minimized by attaching the engine arms at the node points on the crankcase, and by making the body attachments at the node points on the frame. These points can be found readily by the use of a vibration tachometer consisting of a number of tuned reeds.

A recent report of a manufacturer of metal bodies has shown, it was stated, that the characteristic vibration of metal panels can be reduced by spraying an asphalt coating inside, to a thickness of about 1/4 in.

Both Mr. Lítle, in his paper, and William J. Mayer, of the J. G. Brill Co., told of roof-panel vibration troubles that were cured only by the substitution of other material for metal. Other discussion had to do with the vibration of brakes, which is said to be due to a rapid succession of grabs and slips between the lining and the drum.

There was discussion also of vibrations from the road, to which J. W. Watson contributed. He said that a car having a short wheelbase can be made to ride as easily as one with a long wheelbase, but it usually has a much higher period of vibration. If the period at the front end can be reduced to about 105 to 110 vibrations per minute, and the period at the rear to about 75 to 85 vibrations per minute, with a 160-lb. man in the seat, the car will ride very easily.

Seat cushions also came in for consideration. Mr. Mayer and Mr. Lítle agreed that a construction which is air-tight, except for correctly proportioned vent-holes, helps greatly by allowing the use of springs that are soft enough for comfort, and at the same time preventing bottoming.

Scientific Fire-Fighting

Modern Equipment and Methods Described by Two Speakers at Buffalo Section Meeting

FIRE-FIGHTING equipment and methods were considered at the meeting of the Buffalo Section, held on April 2, when 191 members attended the presentation of papers by Hubert Walker, assistant chief engineer, and James Hart, Foamite Division, both of the American-La France & Foamite Corp., Elmira, N. Y. E. W. Kimball, Chairman of the Section, presided.

In outlining the technical requirements of fire fighting and fire protection, Mr. Walker referred to the early beginning of fire fighting and showed the picture of an Egyptian fire engine of more than 2000 years ago. He grouped the main requisites of equipment under four heads: reliability, mobility, availability and adaptability, and pointed out that no fire-engine progress was made until the sixteenth century, when the Germans used a syringe pump fed by buckets. Four-wheeled engine carts came in the eighteenth century, together with a smaller nozzle for better stream-control. This development left only the want for greater availability to be satisfied, which was done by the introduction of leather hose.

The first steam-operated fire pump was built in 1828. Equipment of both increasing capacity and speed, and the substitution of gasoline for steam power, led to the modern fire-engine, which includes a rotary, centrifugal or piston pump, and is subjected to very strict annual inspection by insurance underwriters. Automobile fire-fighting apparatus has an average life of from 15 to 25 years, said Mr. Walker.

The functions of the various types of pump, equipment, engines, ladder trucks, water towers, salvage car and other auxiliary fire equipment were then described.

Smothering Fire with Foam

In the second paper of the evening, on the subject, Foamite Method of Extinguishing Fires, Mr. Hart stated that present fire-fighting methods are to cool the burning materials below the burning point or to smother the fire by excluding oxygen. He described the various types of chemical fire-extinguisher now in use, such as (*a*) the fire-gun, designed to handle carbon tetrachloride; (*b*) the soda-acid extinguisher, containing a solution of sodium bicarbonate and a bottle of sulphuric acid

which, when the bottle is inverted, commingles with the soda solution and produces carbon dioxide gas; (*c*) the All-weather extinguisher, charged with calcium chloride; and (*d*) the Foamite extinguisher.

It was explained that the fourth type consists of an outer shell which holds a solution of sodium bicarbonate to which "Firefoam Liquid" has been added, and an inner cylinder containing concentrated aluminum-sulphate solution. Inversion of the device brings the solutions together, forming "Firefoam," which has the consistency of dense shaving-lather. The chemical reaction producing the foam creates pressure that ejects the foam through a hose and nozzle. The foam floats on the surface of a burning liquid and smothers the fire.

Mr. Hart then briefly reviewed the history of the foam method of fire extinguishing, and listed the six features essential where large oil tanks are to be protected from fire as follows: large Foamite solution tanks; metering pumps handling equal quantities of the two solutions; a simple but adequate piping system; accessible control valves of the indicating type; mixing chambers from which the foam is delivered to the burning oil surface; and auxiliary equipment, such as hydrants, hose and Siamese nozzles.

The discussion dealt mostly with Mr. Hart's paper. When asked about the requisite depth of foam in an 80-ft. diameter tank, he stated that 1 in. is enough, if evenly distributed, to extinguish a fire. In practice, owing to several factors, a depth of 4 or 5 ft. of foam on the oil surface is usual. Success is not a question of thickness of the foam, but of applying it fast enough so that it will not be dissipated by the fire. A member of the Buffalo Fire Department then spoke about a fire on an oil barge 75 ft. long, 20 ft. wide and 8 ft. deep, that two foam generators had failed to extinguish. Mr. Hart stated that he was familiar with the case and that the foam had been applied at too great velocity, so the gas was released before the foam reached the fire. Moreover, water had been applied first, with the result that the oil fire was spread.

Fire Chief Heddon stated that if, in case of a fire in an oil tank large enough to require two Foamite generators, only one generator were immediately available, it would be better to withhold using it until another generator could be obtained and then use both together. Mr. Hart, however, had previously emphasized the importance of having a generator immediately available on an oil barge so that foam could be applied before a fire gained headway, as every minute of delay makes a fire harder to fight.

Production Inspection Trip

Indiana and Dayton Sections Combine in Thoroughly Enjoyable Perfect Circle Visit

MANY features of a varied program combined to make the April 20 meeting of the Indiana and Dayton Sections the most satisfactory production meeting ever held by the Indiana Section. The Indianapolis delegation, headed by Chairman Fred S. Duesenberg and Secretary Harlow Hyde, made the trip to Hagerstown, Ind., in the new steam-electric motorcoach designed by D. McCall White and in the private cars of members in and near Indianapolis. A dozen members of the Dayton Section also made the trip in cars, the whole party numbering more than 100. The steam coach, furnished for the occasion by the Automotive Syndicate, Ltd., of Indianapolis, created a great deal of interest, and in the run from Hagerstown to New Castle and return carried many who had not made the trip down from Indianapolis in it.

The event was an all-day affair, the members and guests of the two Sections meeting before 10 o'clock Saturday morning at the Hagerstown plant of the Perfect Circle Co., where the Teetors were the generous hosts for the occasion. The rest of the forenoon was devoted to a trip through the factory progressively from the rough-stores department to the sacking and shipping department and finally to the laboratory.

Keen interest was taken by the visitors in the various processes of piston-ring manufacture from the pig iron to the finished state in the Hagerstown plant and the New Castle foundry of the company, which employs more than 1200 workmen and produces 5,000,000 piston-rings per month.

Following luncheon at noon as guests of the company, the party rode to the New Castle foundry in the motorcoach and private cars and, after inspecting the foundry, spent the remainder of the afternoon at the New Castle Country Club, through the courtesy of the Perfect Circle Co. Rain which threatened to interfere with the sport ceased after 3 p.m., and about two dozen of the men played golf.

Unique Smoker-Dinner Entertainment

Returning from the Club to Hagerstown, again by road, the party was entertained at a very unusual smoker-dinner at which entertainment was provided by the Perfect Circle Co. orchestra and minstrel troupe. Six of the 16 members of the orchestra and troupe are members of the Teetor family, the others being officials and members of the various staffs of the company. The orchestra played several musical numbers, and, in the words of Secretary Hyde, "the minstrels spattered jokes that rocked the assembly with laughter." This part of the program was followed by two burlesque numbers that were equally funny and popular. Souvenir S.A.E. emblems made into paper-weights enclosed in a Perfect Circle double-duty piston-ring were presented to all the guests at the end of the dinner just before the entertainment started.

The main party left Hagerstown at 10.15 p.m. in the steam motorcoach for Indianapolis and in private cars for Dayton and other home towns.

Indiana Section's May 18 meeting, to be held in Indianapolis, is to be a round-table discussion of the 1930 Indianapolis Race rules and cars, regarding which considerable difference of opinion seems to exist among engineers, factory men and race drivers.

Trask Erroneously Reported

AN unfortunate error occurred in the report of Charles A. Trask's remarks at the February meeting of the Indiana Section, as published in the March issue of the S.A.E. JOURNAL, in which he is reported to have said, with regard to a light four-cylinder car, that it should require "only one change of oil in more than a year." As Mr. Trask is a very strong advocate of adequate lubrication, his acquaintances will recognize the absurdity of attributing such a statement to him. His actual words were: "A 5-gal. can of lubricating oil lasts me about 13 months."

Personal Notes of the Members

Huebotter Joins Waukesha Motor

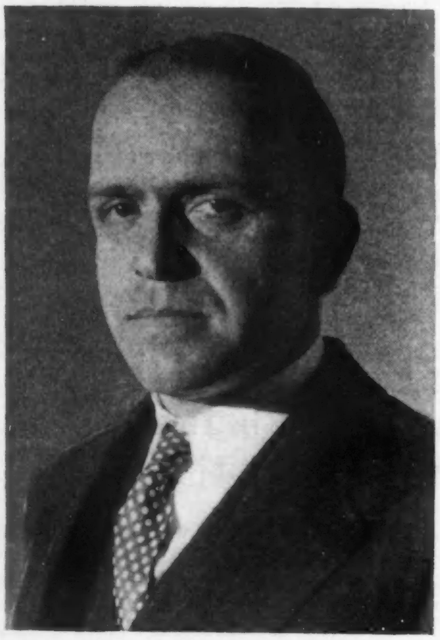
H. A. Huebotter, known for his work in the field of research engineering, has resigned as chief engineer of the Butler Mfg. Co., of Indianapolis, in order to become identified as research engineer with the Waukesha Motor Co., in Waukesha, Wis. His engineering experience, previous to his affiliation with the Butler Mfg. Co., included the following positions: design engineer for the Zip Cycle Car Co., Davenport, Iowa; chief engineer for the Phelps Motor Co., Rock Island, Ill.; and assistant chief inspector for the Waterloo Gas Engine Co., Waterloo, Iowa. In 1921 he was appointed research assistant in the Engineering Experiment Station of Purdue University, his Alma Mater. In 1925 he was named research associate, and in 1927 associate, professor of gas engineering. His connection with the Butler company, made in 1928, marked his return to the commercial field of engineering.

Mr. Huebotter was elected to Society membership in 1922, and for the last four years has served on the Research Committee. Interesting and technically valuable papers have been presented by Mr. Huebotter at meetings of the Society and published in various issues of the S.A.E. JOURNAL. Among those published are: Aluminum-Alloy Pistons in Gasoline and Oil Engines, printed in THE JOURNAL of March, 1928; and Vibration in Automobile Engines, published in the July, 1928, issue of THE JOURNAL. Mr. Huebotter collaborated with G. A. Young and J. H. Holloway in the preparation of the paper, Internal-Combustion Engine Characteristics Under High Compression, which appeared in the January, 1923, issue of THE JOURNAL and in Part I of TRANSACTIONS for that year.

Ruthenburg Named President of Copeland Products

Louis Ruthenburg, who until lately was vice-president and assistant general manager of the Yellow Truck & Coach Mfg. Co. and of its subsidiaries, the General Motors Truck Co. and the General Motors Truck Corp., of Pontiac, Mich., is the new president and general manager of Copeland Products, Inc., of Detroit. His engineering career has been of great interest. He joined the E. C. Walker Mfg. Co. in 1907 as engineer and designer. In 1909 he went to London and spent a year studying European car design. While there he was connected with the Brush Electrical Engineering Co., Ltd. The year following his visit in London he engaged in independent automobile engineering and during this time wrote a number of technical articles which appeared in such publications as *Horseless Age*, *Motor*, the *Automobile Trade Journal* and the *Sportsman and Motorist.*

In 1911 Mr. Ruthenburg became chief engineer and factory manager of the Electric Vehicle Co., in Louisville, Ky., which was absorbed by the Kentucky Wagon Mfg. Co., also of Louisville, in which organization he operated in a similar capacity, until he entered upon



LOUIS RUTHENBURG

his long affiliation with the Dayton Engineering Laboratories Co. While with this company, he successively held the positions of assistant chief engineer, chief inspector, and general superintendent. In 1922, Mr. Ruthenburg acted as manager of the manufacturing division of the General Motors Research Laboratory. In 1923, he undertook the management of the Yellow Sleeve Valve Engine Works, Inc., of East Moline, Ill., a subsidiary of the Yellow Cab Mfg. Co. which, in 1925, as the Yellow Truck & Coach Mfg. Co., was merged with General Motors interests. In 1927, he was elected vice-president and assistant general manager of the Yellow Truck & Coach Mfg. Co., with headquarters in Detroit, in which position he assumed responsibility for the design and construction of the $8,000,000 manufacturing plant at Pontiac.

Mr. Ruthenburg has been a Member of the Society for many years, having joined in 1911 during the early years of its existence. He joined the Dayton Section in 1922, transferred his Section affiliation to Chicago in 1926 and to the Detroit Section in 1928.

An interesting paper by Mr. Ruthenburg, published in the October, 1925, issue of THE JOURNAL, is entitled, Training the Foremen of a Manufacturing Organization.

Peterson Goes with Brown-Lipe

Carl D. Peterson has severed his connection with the Durant Motor Co., at Elizabeth, N. J., to take up the duties of chief engineer with the Brown-Lipe Gear Co., of Syracuse. His early engineering experience was acquired in the service of the Babcock & Wilcox Co., located at Barberton, Ohio, and the International Harvester Co., in Akron. In 1912 he entered upon his connection with the Lippard-Stewart Motor Car Co., in Buffalo. His first position with this company was as assistant engineer, successive promotions resulting in his holding the title of chief engineer and factory manager. He gave up this post in 1919 to act in a similar capacity for the H. J. Koehler Motors Corp., in Newark, N. J., and in 1923 joined the Durant Motor Co.

Mr. Peterson has manifested a keen interest in Society work during his membership, which dates back to 1912. Axle Ratios and Transmission Steps is the subject of a constructive paper presented by him at the Annual Meeting last January and published in this issue of the S.A.E. JOURNAL.

R. E. Wilson Advanced

Robert E. Wilson was recently named assistant to the vice-president in charge of manufacturing of the Standard Oil Co. of Indiana. His principal duties will be to direct the work of the newly organized Development, Patent and Trademark department. Before this promotion Mr. Wilson, who is an accepted authority on the subjects of motor fuels and lubricants, was a member of the Research Council of the company. He joined the Standard Oil Co. in the latter capacity in 1923, following his resignation from the faculty of the Massachusetts Institute of Technology, of which he had been a member since 1919. Mr. Wilson graduated from the College of Wooster in 1914, and in 1916 from M. I. T., where he remained

as research associate in applied chemistry for one year. In 1917 he accepted the position of consulting chemical engineer with the Bureau of Mines, and in 1918 served as captain and major in the Chemical Warfare Service. The next year he went to M.I.T. in the capacity of director of research in the research laboratory of applied chemistry.

Mr. Wilson became a member of the Society in 1921 and of the Mid West, later called the Chicago, Section in 1923. His membership in the Society has been marked by an active participation in National and Section matters. In 1923 he acted as Chairman, and in 1924 as Vice-Chairman, of the Mid West Section. He has served several times on the Sections Committee, representing the Chicago Section in 1927 and in 1928 functioning as a member-at-large. His service on the Research Committee, of which he has been a member every year since 1924, has been most valuable; and he has been equally active in the work of the Fuels Subcommittee, on which he served as Chairman in 1927. In 1928 he represented the Society on the Cooperative Fuel-Research Steering Committee of the National Automobile Chamber of Commerce and the American Petroleum Institute. This year marks his third term of service on the Lubricants Division of the Research Committee.

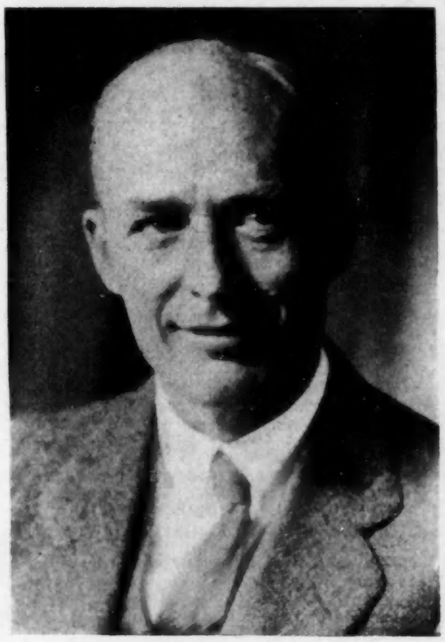
Mr. Wilson has delivered many papers at S.A.E. meetings which constitute a remarkably interesting and informative record of engineering data. His paper at the Chicago Fuel Session on the measurement of motor-fuel volatility is contained in the January, 1922, issue of THE JOURNAL, and a discussion on the Dew Point of Gasoline was printed in the October, 1921, issue of THE JOURNAL. He has collaborated with D. P. Barnard 4th in the preparation of many papers, including the following: The Measurement of the Property of Oiliness, published in THE JOURNAL of August, 1922, and in Part I of the corresponding TRANSACTIONS; Condensation Temperatures of Gasoline and Kerosene-Air Mixtures, printed in the November, 1921, issue of THE JOURNAL; Further Data on the Effective Volatility of Motor Fuels, appearing in THE JOURNAL of March, 1923, and in Part I of the 1923 TRANSACTIONS; and Total Sensible Heats of Engine Fuels and Their Mixtures with Air, printed in the January, 1922, issue of THE JOURNAL. A Suggested Remedy for Crankcase-Oil Dilution is the title of a paper published in THE JOURNAL of February, 1926, in the preparation of which Mr. Wilson was co-author with R. E. Wilkin.

Mr. Wilson is also a member of the American Institute of Chemical Engineers, the American Chemical Society and the American Society for Testing Materials.

Geisse in New Organization

John H. Geisse, who until lately was chief engineer in charge of the aeronautical engineering laboratory of the Naval Aircraft Factory, at Philadelphia, will be vice-president of engineering in the Comet Engine Corp., a recently organized company which has purchased the rights to the Comet engine and, in consolidation with the Gisholt Co., will manufacture engines in Madison, Wis.

Mr. Geisse has been interested in aeronautical engineering ever since his service as second lieutenant in the Army Air Service during the World War. His duties while in the Air Service were those of chief of the power-



JOHN H. GEISSE

plant section of the Engineering Division. At the end of the war he continued in the Air Service for one year, when he joined the Wright Aeronautical Corp., assuming charge of the experimental work in aeronautic powerplants. He resigned two years later to accept the position he is now leaving.

Elected to membership in the Society in 1923, Mr. Geisse has taken an important part in Society activities. He joined the Pennsylvania Section in 1926 and was chosen Vice-Chairman of that Section last year.

Carlson's New Position

R. E. Carlson, formerly in charge of automotive lighting at the Edison Lamp Works of the General Electric Co., at Harrison, N. J., recently established a connection with the Westinghouse Lamp Co., of Bloomfield, N. J. His new position is that of commercial engineer.

Mr. Carlson's engineering activities have been divided between military and civilian service. In 1912 he joined the Westinghouse Electric & Mfg. Co., at East Pittsburgh, Pa., as a student, being appointed sales and industrial engineer in 1913. He held this position until 1915, when he accepted the vice-presidency of C. A. Hoppin & Co., of Peoria, Ill. In 1917 he joined the Ordnance Department of the United States Army, with the rank of captain, and was later made a major. He served 18 months overseas as Assistant Commissioner of the Anglo-American Tank Commission, and remained in the Army after the war taking up the duties of chief of the Ordnance Department and assuming charge of tank development work. In 1923 he left the military service to become an engineer in the Bureau of Standards. Two years later he joined the Edison Lamp Works.

Mr. Carlson was elected a Service Member of the Society in 1921 and joined the Washington Section in 1924. In 1927, at the time of his affiliation with the Edison Lamp Works, he joined the Metropolitan Section. Ever since becoming a member, Mr. Carlson, who is one of the outstanding automotive lighting experts of the country, has taken a prominent part in the standardization work of the Society. He has served every year since 1924 on the Lighting Division of the Standards Committee and this year is also a member of the Headlight Research Subcommittee. He is the author of various papers on the subject of headlighting, including the following: Economic Motor-Fuel Volatility, appearing in the February, 1923, issue of THE JOURNAL and in Part I of TRANSACTIONS for that year; Headlighting Situation in the District of Columbia, published in the April, 1926, issue of THE JOURNAL; and the Effect of Wet Roads on Automotive Headlighting, prepared in collaboration with W. S. Hadaway, and printed in THE JOURNAL of July, 1927.

Dingley Now Stutz Vice-President

Bert Dingley, who was made vice-president in the recent election of new officers of the Stutz Motor Car Co. of America, has had an unusually interesting and varied career as an engineer. About 1905 he started racing, and during several years competed in many events. He then became interested in building cars and aided in the construction of numerous speedsters, building the speed car named ONO during the years 1914 to 1916. In 1917 he entered the Bureau of Aircraft of the Army as inspector, and in 1919 joined the forces of the Nordyke & Marmon Co., at Indianapolis. While with this company he held the positions of sales representative and service manager. Severing this connection in 1925, he became

(*Continued on p.* 36)

Applicants Qualified

The following applicants have qualified for admission to the Society between March 10 and April 10, 1929. The various grades of membership are indicated by (M) Member; (A) Associate Member; (J) Junior; (Aff.) Affiliate; (S M) Service Member; (F M) Foreign Member.

BEALL, WELLWOOD E. (J) student, New York University; (mail) Box 140, New York University, University Heights, *New York City.*

BLAKE, EDWARD C. (A) proprietor, Blake Motor Car Co., 719 Main Street, *New Rochelle, N. Y.*

BRANAN, FURNIE CASWELL (A) chief instructor, Nashville Automobile School, 107-12th Avenue North, *Nashville, Tenn.*

CHAILLOT, RENE (M) mechanical engineer, Michelin Tire Co., *Milltown, N. J.;* (mail) 146 Church Street.

CHILDS, STERRY HUNT (M) vice-president, treasurer, general manager, Hendey Machine Co., *Torrington, Conn.*

CLARK, H. HOY (J) engineer, Cleveland Wire Spring Co., 1281 East 38th Street, *Cleveland.*

COMBER, FRANCIS WILLIAM (M) superintendent of motor vehicles, Bell Telephone Co. of Pennsylvania, *Philadelphia;* (mail) 4439 Paul Street.

COTTRELL, JAMES W. (A) technical editor, *Commercial Car Journal Operation and Maintenance,* Chilton Class Journal Co., Philadelphia; (mail) 409 Bellevue Avenue, *Hammonton, N. J.*

CULLEN, W. J. (J) sales engineer, Sinclair Refining Co., *New York City;* (mail) c/o Clement, 327 West 85th Street.

DANIELS, GEORGE W. (M) vice-president, treasurer, director, Daniels & Kennedy, Inc., New York City; assistant to president, executive vice-president, U. S. Trucking Corp., 14 Coenties Slip, *New York City;* (mail) U. S. Trucking Corp.

DART, EDWARD W. (J) engineer, aircraft division, Ford Motor Co., *Dearborn, Mich.;* (mail) 107 East Garrison Avenue.

DENNISON, HERBERT J. S. (M) patent attorney, 1007 Federal Building, 85 Richmond Street, West, *Toronto 2, Ont., Canada.*

DIAMOND, JAMES E. (M) general manager, Aircraft Devices Corp., 347 Madison Avenue, *New York City.*

DIEDRICHS, GERMAN CARLOS (J) aeronautical engineer, Aircraft Development Corp., Grosse Ile, Mich.; (mail) 852 Delaware Avenue, *Detroit.*

DOBBINS, ROBERT N. (A) chief mechanic, Colonial Airways System, Albany, N. Y.; (mail) Osborn Road, *West Albany, N. Y.*

EDELMAN, ALBIN DANA (J) engineer, Hyatt Roller Bearing Co., *Harrison, N. J.*

FUNDERBURK, OTIS C. (M) president, Vacturi Carburetor Co., 1253 Diversey Parkway, *Chicago.*

GAIDZIK, GEORGE WILLIAM (M) special representative conducting sales schools, Dodge Bros. Corp., Detroit; (mail) 206 Belle Avenue, *Highland Park, Ill.*

GEERS, J. F. (A) president, general manager, Index Machinery Corp., 1860 Broadway, *New York City.*

GLASS, JOS. A. (A) owner, Automotive Service Co., 3518 Fifth Avenue, *Pittsburgh.*

GRIFFITHS, CHARLES R. (A) sales engineer, heavy duty bumper division, C. G. Spring & Bumper Co., Cleveland; (mail) 14208 Scioto Avenue, *East Cleveland, Ohio.*

GRUNDMANN, WILLIAM R. (A) automotive engineer, Texas Co., *Denver.*

HAYDEN, A. A. (M) engineer, Carter Carburetor Corp., 2838 North Spring Street, *St. Louis.*

HECKMAN, JOHN L. (A) sole owner, Heckman Machine Works, 4026 West Lake Street, *Chicago.*

HEINRICHS, ROBERT M. (J) assistant director of sales, Bendix Brake Co., 401 Bendix Drive, *South Bend, Ind.*

HEISER, GEORGE (A) owner, general manager, Heisers, Inc., 1406 Tenth Avenue, *Seattle.*

HILE, FOREST C. (J) draftsman, Bendix Brake Co., *South Bend, Ind.;* (mail) 520 West Washington Avenue.

HODGKINS, H. FOLLET (A) general manager, W. C. Lipe, Inc., 208 South Geddes Street, *Syracuse, N. Y.*

HOOT, E. A. (A) service manager, Eldridge Buick Co., *Spokane, Wash.*.

HOWATT, GERALD (M) treasurer, Howatt & Lee, Inc., 3102 Northern Boulevard, *Long Island City, N. Y.*

HUGHES, JAMES W. (M) staff engineer for vice-president in charge of manufacturing, Dodge Division, Chrysler Corp., *Detroit;* (mail) The "Wardell," 15 Kerby, East.

JENKINS, ABB (M) vice-president, managing director, Imperial Motors, Ltd., 321 Seventh Avenue, West, *Calgary, Alta., Canada.*

JONES, JOSEPH H. (A) factory representative, engineering department, Studebaber Corp., *South Bend, Ind.;* (mail) 1810 South Caroline Street.

JONES, RALPH F. (M) mechanical engineer, Russell Mfg. Co., *Middletown, Conn.;* (mail) P. O. Box 712.

JONES, WALTER M. (M) manager, automotive division, Keasbey & Mattison Co., Ambler, Pa.; (mail) 6489 Malvern Avenue, *Philadelphia.*

LAMPE, FRIEDRICH WILHELM (J) technical man, Chrysler Corp., *Detroit;* (mail) P. O. Box 141, North End Station.

LAUTZENHISER, FRED B (A) sales engineer, International Harvester Co. of America, 606 South Michigan Avenue, *Chicago.*

LEIVISKA, YRJO (A) salesman, Pohjoismaiden Autotuontiooy, Helsinki, Suomi, Finland; (mail) Museokatu, 9 B, *Helsinki, Suomi, Finland.*

LIVINGSTON, WILLIAM M. (M) superintendent of motor vehicles, Town of Montclair, *Montclair, N. J.;* (mail) 11 Patton Place.

MONTGOMERY, DONALD H. (A) treasurer, chief engineer, Gridley Machine Co., Hartford, Conn.; (mail) *Berlin, Conn.*

MUSIEL, HARRY W. (M) designing engineer, charge of body construction, Heisers, Inc., *Seattle;* (mail) 2525-30th Avenue, South.

MYERS, FRANCIS P. (M) president, manager, Myers-Blackwell Co., *Portland, Ore.;* (mail) 55 Union Avenue.

NESS, NORMAN R. (M) assistant mechanical engineer, Minneapolis Steel & Machinery Co., 2854 Minnehaha Avenue, *Minneapolis.*

OBERG, A. W. (A) service superintendent, Central Agency, Inc., *Seattle;* (mail) 9018 Wallingford Avenue.

OLDACRE, WILLIAM H. (A) factory manager, D. A. Stuart & Co., *Chicago;* (mail) 2733 South Troy Street.

PAYNE, A. O. (M) chief engineer, Parks Aircraft, Inc., St. Louis, Mo.; (mail) 110 Hazel, Edgemont Station, *East St. Louis, Ill.*

PHILIPS, EDWIN S. (M) president, Philbrin Corp., *Kennett Square, Pa.;* (mail) P. O. Box 115.

PLATT, MAURICE (F M) technical editor, *The Motor,* Temple Press, Ltd., 5 Rosebery Avenue, *London E. C. 1, England.*

SALZMAN, GEORGE S. (M) vice-president, general manager, Monmouth Products Co., 882 East 72nd Street, *Cleveland.*

SCHRAGG, T. F. (J) automotive application engineering department, Timken Roller Bearing Co., *Canton, Ohio.*

SCHWEDES, HAROLD F. (A) tool designer, Fairchild Airplane Mfg. Corp., Farmingdale, N. Y.; (mail) Cedar Street, *Hempstead, N. Y.*

SHENSTONE, B. S. (J) research assistant in aeronautics, University of Toronto, *Toronto, Ont., Canada;* (mail) 17 Wychwood Park.

SHEPPARD, A. G. (J) designing engineer, American LaFrance Fire Engine Co., *Elmira, N. Y.;* (mail) 112 Hoffman Street.

SICKLESTEEL, DAVID T. (M) chief engineer, Detroit Gear & Machine Co., 670 East Woodbridge Street, *Detroit;* (mail) 9162 Cheyenne Street.

SKAGGS, ARTHUR G. (A) sales, service, Main Line Auto Co., 502 South K Street, *Tulare, Cal.;* (mail) P. O. Box 942.

SMILING, BRUNO M. (M) assistant chief draftsman, Sikorsky Aviation Corp., *College Point, N. Y.*

SMITH, ARTHUR E. (A) president, treasurer, Smith & Gregory of New York, Inc., New York City; (mail) 471 Amity Street, *Flushing, N. Y.*

SMITH, BARTLETT JOSEPH (A) manager of national account sales, Autocar Co., Ardmore, Pa.; (mail) 549 West 23rd Street, *New York City.*

SNEAD, ARTHUR R. (A) 1214 Elmwood Boulevard, *Dallas, Tex.*

SODERQUIST, ALBERT A. (J) stress engineer, Boeing Airplane Co., *Seattle.*

SOMERVILLE, GEORGE N. (M) manager, engineer, industrial division, Atlas Imperial Diesel Engine Co., Oakland, Calif.; (mail 1240 Carlotta Avenue, *Berkeley, Calif.*

STEELE, ELMER T. (A) service manager, Wagner Motors, Inc., Tacoma; (mail) 1750 Belmont Street, *Portland, Ore.*

STENGEL, J. FRANK (A) director, manager, automotive division, Dictograph Products Corp., New York City; (mail) 100-34 194th Street, *Hollis, N. Y.*

STUCK, HENRY H. (A) production manager, Thompson Products, Inc., 7881 Conant Road, *Detroit.*

SUBASKY, A. J. (A) machine designer, Poole Engineering & Machine Co., 4807 Fleet Street, *Baltimore.*

TAYLOR, C. H. (M) consulting engineer, Bendix Brake Co., 4-129 General Motors Building, *Detroit.*

TEJADA, J. DE D. (A) technical translator, San Ignacio 50, *Havana, Cuba.*

THOMSON, J. E. (A) manufacturers' representative, Firestone Tire & Rubber Co., Canfield and Woodward Avenues, *Detroit.*

TIFFANY, H. R. (J) secretary, D. H. Tiffany Corp., *Rochester, N. Y.;* (mail) 125 Fallison Road.

WALDNER, ERNEST (A) designer, (draftsman) special engineering department, Oakland Motor Car Co., Pontiac, Mich.; (mail) P. O. Box 619, *Birmingham, Mich.*

WEISS, ERWIN A. (M) Willys Overland, Inc., *Toledo;* (mail) 4126 North Lockwood Avenue.

WILBER, WALLACE E. (M) mechanical engineer, manufacturing division, Cadillac Motor Car Co., *Detroit;* (mail) 870 Gladstone Avenue.

WILES, CHARLES L. (M) general superintendent, Budd Wheel Co., *Detroit;* (mail) 4669 Lakewood Avenue.

WIRTH, CHARLES E. (A) assistant general sales manager, Frontier Mfg. Co., North Tonawanda, N. Y.; (mail) 78 North Spring Garden Avenue, *Nutley, N. J.*

Applicants for Membership

The applications for membership received between March 15 and April 15, 1929, are listed below. The members of the Society are urged to send any pertinent information with regard to those listed which the Council should have for consideration prior to their election. It is requested that such communications from members be sent promptly.

ADKINS, FRANK LUCE, general superintendent, Joseph Kreutzer Corp., *Los Angeles.*

ALLEN, JOSEPH W., chief electrical unit, materiel division, United States Air Corps, *Dayton, Ohio.*

ATZBERGER, FRANK X., Frank X. Atzberger, 126 Paulison Ave., *Ridgefield Park, N. J.*

BALL, CRISSY K., acting general factory manager, American LaFrance & Foamite Corp., *Elmira, N. Y.*

BEACH, FREDERIC SEWARD, chief draftsman, Northwestern Electric Co., *Portland, Ore.*

BEAMON, E. L., test engineer, Tide Water Oil Co., *Bayonne, N. J.*

BECRAFT, GEORGE F., proprietor, Pacific Automotive Sales & Service, *Oakland, Cal.*

BERTRAN, EDWARD M., chief engineer, aircraft division, Brewster & Co., *Long Island City, N. Y.*

BODE, LOUIS A., service man, International Motor Co., *New York City.*

BODY, RAYMOND G., field engineer, The B. F. Goodrich Co., *Akron, Ohio.*

BRIDGES, KENNETH L., special representative, automotive aviation division, American Lithographic Co., Inc., *New York City.*

BROPLEY, CARL RAYMOND, mechanic foreman, Portland-Seattle Auto Freight Co., *Portland, Ore.*

BROWN, DOUGLAS M., engineering follow-up, Graham-Paige Motor Car Co., *Detroit.*

BUHLMAN, FRANK HENRY, chief engineer, Rollway Bearing Co., Inc., *Syracuse, N. Y.*

BUTTORF, HARRY E., supervision of transportation, Fisher Body Corp., *Detroit.*

CARRINGTON, JAMES E., vice-president, Composite Piston Co., *Detroit.*

CAWTHORN, CLAUDE SCOTT, automotive equipment manager, Cutten & Foster, Ltd., *Toronto, Ont., Canada.*

CULTER, RALPH E., salesman, Ferodo & Asbestos, Inc., *Portland, Ore.*

CUSON, LEE A., sales engineer, H. W. Holmes Corp., *Detroit.*

DI GIOVANNI, LOUIS, systematizer, planning department, E. G. Budd Mfg. Co., *Detroit.*

EARL, HARRY W., president and chief engineer, Earl Aircraft Corp., *Portland, Ore.*

FABLE, CHARLES E., service manager, Kings County Buick, Inc., *Brooklyn, N. Y.*

FAHEY, O. M., partner, Gill & Fahey, *Spokane, Wash.*

FEAVER, CHARLES J., director and general service superintendent, Giles Rice & Peters, Ltd., *Toronto, Ont., Canada.*

FOSTER, A. H., superintendent, Toronto Transportation Commission, *Toronto 3, Ont., Canada.*

FRINK, JAMES H., assistant to the manager, Washington Iron Works, *Seattle.*

FUHRY, EDMUND, engineer in charge of experimental dynamometer laboratory, Olds Motor Works, *Lansing, Mich.*

GEILER, ALFRED LEBRECHT, service promotion, General Motors Export Co., *New York City.*

GIBNEY, LYMAN H., president and general manager, Associated Die & Tool Co., *Flint, Mich.*

GILL, H. M., service engineer, Twin Coach Corp., *Kent, Ohio.*

GILLIES, BREWSTER ALLISON, vice-president, Grover Loening Co., Inc., *New York City.*

GLIDEWELL, JAMES E., drafting, layouts, Hall-Scott Motor Car Co., *Berkeley, Cal.*

GOLDMAN, SIDNEY H., Curtiss Aeroplane & Motor Co., *Garden City, L. I., N. Y.*

GOULD, WILLIAM CRACKEL, independent aeronautical research, 410 Congress Bldg., *Detroit.*

GREENBERG, WILLIAM, Box 59, *Whitestone, N. Y.*

GRIFFIN, WILLIAM, garage foreman, Crown Mills, *Portland, Ore.*

HALE, H. DUDLEY, copywriter, technical and sales papers, automotive clients, United States Advertising Corp., *Toledo.*

HARTNEY, HAROLD E., president, Aviation Business Bureau, Inc., *New York City.*

HANSEN, GUSTOF L., superintendent, Gear Grinding Machine Co., *Detroit.*

HANSEN, O. ARNOLD, automotive engineer, Linde Air Products Co., *Buffalo.*

HANUS, JOSEPH P., research engineer, The Skoda Works, Ltd., *Prague, Czechoslovakia.*

HAY, MALCOLM, supervisor, new car deliveries, student mechanical department, The White Co., *Long Island City, N. Y.*

HENDERSON, M. B., salesman, Motor Parts Co., *Oakland, Cal.*

HERGENROETHER, ERNEST J., research and development, automotive department, International Nickel Co., *Detroit.*

HOGBEN, WILLIAM H., sales manager, Ditzler Color Co., *Detroit.*

HOGLUND, GUSTAV O., assistant professor of aeronautical engineering, University of Minnesota, *Minneapolis.*

JONES, FRANK HUBERT, assistant export service manager, Willys-Overland Crossley, Ltd., Heaton Chapel, *Stockport, England.*

JONES, IRA MILTON, patent lawyer, 68 East Wisconsin Avenue, *Milwaukee.*

KEATING, J. B., superintendent in charge of transportation and operation, Motor Mileage Corp., *New York City.*

KELLEY, RUSSELL T., president, Hamilton Advertisers' Agency, Ltd., 17 Main Street, East, *Hamilton, Ont., Canada.*

KELSEY, KEIGH, engineer, Murray & Flood; engineer and secretary-treasurer, National Parking Garages, Inc.; secretary and treasurer, National Parking Security Corp., *New York City.*

KNUDSON, JAMES F., JR., draftsman and checker, Curtiss Aeroplane & Motor Co., *Garden City, L. I., N. Y.*

KUHLMAN, GEORGE W., eastern district manager, The Hall Co., *Milwaukee.*

LAVERTY, FRANCIS W., test and research work, Clark Brothers Co., *Olean, N. Y.*

LEMON, JOSEPH R., mechanical engineer, Ex-Cell-O Tool & Mfg. Co., *Detroit.*

LENNSTRAND, GUY S., supervisor, Dodge Division, Chrysler Corp., *Detroit.*

LENZ, H. F., production manager, Kinner Airplane & Motor Corp., *Glendale, Cal.*

LEWIS, GEORGE K., director of engineering, Met-L-Wood Corp., *Chicago.*

LOMBARD, CHARLES WILSON, department head, automobile mechanics' course, Murray Vocational School, *Charleston, S. C.*

LUCAS, JOSEPH A., superintendent, Winfield carbureter department, Haiden Auto Parts, Inc., *Oakland, Cal.*

MCGUIRE, R. M., vice-president, H. W. Holmes Corp., *Detroit.*

MENASCO, A. S., president, Menasco Motors, Inc., *Los Angeles.*

MERITHEW, ROBERT S., student engineer, H. H. Franklin Mfg. Co., *Syracuse, N. Y.*

MESINGER, FREDERICK WILLIAM, district manager, Norma Hoffmann Bearings Corp., *Stamford, Conn.*

MUNGER, MYRON T., mechanical draftsman (layout man), Kinner Airplane & Motor Corp., *Glendale, Cal.*

NEET, ORA R., salesman, The Wiggins Co., Inc., *Portland, Ore.*

PAYNE, MATT, technical advisor, Clayton Wagons, Ltd., Abbeywood, *Lincoln, England.*

PEASE, ROBERT M., manager, St. Louis branch plant, Axelson Machine Co., *Los Angeles.*

POTTS, ALLEN D., metallurgist, Simonds Saw & Steel Co., *Lockport, N. Y.*

REID, F. MALCOLM, chief engineer, Fruehauf Trailer Co., *Detroit.*

RENWICK, JOHN WARD, partner and manager, C. W. Renwick, *Portland, Ore.*

RIGHTER, WALTER H., draftsman, Kinner Airplane & Motor Corp., *Glendale, Cal.*

ROHRBACHER, EARL W., engine design draftsman, Hupp Motor Car Corp., *Detroit.*

ROSS, THURSTON H., consulting engineer, chairman, department of industrial management, University of Southern California, *Los Angeles.*

SCHAEFER, WILLIAM H., manager, manufacturers' sales, Buffalo branch, Goodyear Tire & Rubber Co., Inc., *Buffalo.*

SCHEBERA, ERNST, president and general manager, Fleetwood Body Corp., *New York City.*

SCHEER, SERGE, engineer, Bedford Petroleum Co., *Paris, France.*

SEAMAN, MILTON L., student, University of Maryland, College Park, *Baltimore.*

SEE, MARCEL, president, Société Anonyme Francaise d'Automobiles Amilcar, *Saint Denis, France.*

SERVAIS, F. P., research engineer, Chrysler engineering department, Chrysler Corp., *Detroit.*

SHEPHERD, B. F., metallurgist, Ingersoll-Rand Co., *Phillipsburg, N. J.*

SIEDSCHLAG, KARL G., industrial engineer, American Hard Rubber Co., *New York City.*

SIROTEK, JOSEPH, president and general manager, Illinois Auto Electric Co., *Chicago.*

SMITH, MAYNARD SANFORD, mechanical draftsman, Ottawa Car Mfg. Co., Ltd., *Ottawa, Ont., Canada.*

STANWICH, JOSEPH F., draftsman, Dole Valve Co., *Chicago.*

STEWART, H. W., division manager, emulsion division, Republic Paint & Varnish Works, *Detroit.*

STIEBER, HERMAN L., senior inspector of naval material, Bureau of Aeronautics, Navy Department, attached to Wright Aeronautical Corp., *Paterson, N. J.*

STROUD, WILLIAM RICHARD, truck inspector, Van Sciver Corp., *Philadelphia.*

STRUSS, O. A., service manager, Mansfield Chevrolet Co., *Vancouver, Wash.*

TABOR, JAMES W., aviation mechanic, Universal Air Lines System, *Chicago.*

THOMPSON, JOSEPH R., 54 South Second Avenue, *Mount Vernon, N. Y.*

TODD, JAMES F., general sales manager, General Motors Near East S/A, *Alexandria, Egypt.*

UNIVERSAL MOTOR, Co., *Oshkosh, Wis.*

VILLIGER, HERMAN J., inspector and service salesman, Studebaker Sales Co. of Chicago, *Chicago.*

VIRIOT, CHARLES A., managing director, vice-president, Repusseau, 77 Rue Danton, *Levallois-Perret, Seine, France.*

WAGNER, WILLIAM R., time-study, Dodge Bros., *Detroit.*

WALKER, GEORGE SUTHERLAND, president, Sunset Tire Corp., *Portland, Ore.*

WALWORTH, WILLIAM M., engineering laboratory, Reo Motor Car Co., *Lansing, Mich.*

WARD, ROSS N., service superintendent, Mack International Motor Truck Corp., *Portland, Ore.*

WEEKS, H. C., new-car service foreman, Chase Garfield Motor Co., *Portland, Ore.*

WESSON, CHARLES W., research engineer, Marvel Carburetor Co., *Flint, Mich.*

WHITCOMB, S. D., student and mechanic, Seth Whitcomb, *Homer, Mich.*

WHITE, HARRY HALL, assistant repair service manager, The White Co., *Cleveland.*

WHITTELSEY, H. NEWTON, president, Whittelsey Body Co., *Bridgeport, Conn.*

Notes and Reviews

These items, which are prepared by the Research Department, give brief descriptions of technical books and articles on automotive subjects. As a general rule, no attempt is made to give an exhaustive review, the purpose being to indicate what of special interest to the automotive industry has been published.

The letters and numbers in brackets following the titles classify the articles into the following divisions and subdivisions: *Divisions*—A, Aircraft; B, Body; C, Chassis Parts; D, Education; E, Engines; F, Highways; G, Material; H, Miscellaneous; I, Motorboat; J, Motorcoach; K, Motor-Truck; L, Passenger Car; M, Tractor. *Subdivisions*—1, Design and Research; 2, Maintenance and Service; 3, Miscellaneous; 4, Operation; 5, Production; 6, Sales.

AIRCRAFT

Full Scale Tests on a Thin Metal Propeller at Various Tip Speeds. Report No. 302. By Fred E. Weick. Published by the National Advisory Committee for Aeronautics, City of Washington; 14 pp., illustrated. [A-1]

It is known that the non-dimensional coefficients of thrust, power, and efficiency, in terms of which propeller characteristics are usually expressed, vary with size and speed; and the size and speed of a propeller are conveniently represented by its tip speed in the plane of rotation.

Tests had been made previously on model propellers at various tip speeds and also on small model airfoils at various air velocities up to and beyond the velocity of sound in air. Both sets of tests indicated a serious change in coefficients at the higher speeds, particularly in regard to airfoil drag coefficients and propeller efficiencies. These tests also indicated that the effect of high speed is less for thin than for thick sections.

The investigation described in this report is the first to obtain the effect of tip speed on the coefficients of a full-scale thin-bladed metal propeller on an actual airplane in a wind-tunnel. The tip speeds reached represent the maximum ordinarily found in practice, but according to the author were not quite so high as desired. However, even to obtain these tip speeds, it was necessary to set the propeller, which was of the adjustable type, to an unusually low pitch. It was found that the effect of tip speed on the propulsive efficiency was negligible within the range of the tests, 600 to 1000 ft. per sec. The tests, states the author, should be taken as only the first step in a more complete investigation to be made in the near future.

Full-Scale Wind-Tunnel Tests of a Series of Metal Propellers on a VE-7 Airplane. Report No. 306. By Fred E. Weick. Published by the National Advisory Committee for Aeronautics, City of Washington; 18 pp., illustrated. [A-1]

It has been known for some time that, in general, thin metal propellers are somewhat more efficient than wooden ones. Actual comparative values have not, however, been available. The present full-scale tests on a series of metal propellers give, for the first time, data on the aerodynamic characteristics of full-size metal propellers and make possible a direct comparison between the metal propellers and a series of wooden propellers tested under the same conditions.

A two-bladed adjustable-pitch metal propeller was tested at five different blade settings, giving in reality a series of propellers varying in pitch. The efficiencies were found to be from 4 to 7 per cent higher than those of standard wooden propellers operating under the same conditions. The results are given in convenient form for use in selecting propellers for aircraft.

Determination of the Rates of Descent of a Falling Man and of a Parachute Test Weight. Air Corps Technical Report No. 2916. Published by the Chief of the Air Corps, City of Washington; 7 pp. [A-1]

The object of these experiments was to determine the instantaneous and maximum rates of descent of (*a*) a dummy man equipped with a dummy parachute-pack and harness, and (*b*) a 200-lb. lead weight with trailing dummy parachute-pack. According to the report, there seemed to be no definite information as to the rate of acceleration and the limiting velocity of a man after leaping from an airplane in flight. This knowledge is of vital importance to those designing and testing parachutes and to anyone who may at some time be forced to use a parachute at a low altitude or wish to delay the action of his parachute to avoid entanglement in falling wreckage or to evade enemy gunners in time of war.

It has been the practice of the Materiel Division to use lead weights and parachute packs equipped with time fuses to test experimental parachutes for strength, but it was not known definitely what speed and momentum were obtained by a delay of any given number of seconds. The data obtained in these tests will assist in clarifying previous records and establishing a basis for future work of this nature.

It may be concluded from the results of these tests that a man equipped with a parachute pack, but allowing it to remain closed, will fall at a maximum rate of between 160 and 175 ft. per sec., and that he will gain this velocity in about 12 sec., having fallen about 1400 or 1500 ft.

It appears that the lead-weight unit reaches a velocity of about 302 ft. per sec. in 15 sec., having fallen about 3000 ft., and is very near its maximum velocity at that time.

Photographic charts and plotted curves are included for use in obtaining velocities, accelerations and distances.

The Machinery Installation of Airship R-101. By T. R. Cave-Browne-Cave. Published in *The Journal of the Royal Aeronautical Society*, March, 1929, p. 175. [A-1]

An article giving a detailed description of the construction of the R-101 was reviewed recently in these columns. Wing Commander Cave-Browne-Cave covers the machinery installation and discusses the experimental work that led up to the adoption of an engine designed to use heavy fuel-oil. According to the author, reliability of the machinery and safety from fire were the main objectives that guided the selection of materials and equipment in the construction of the airship. Safety has been sought by the use of heavy fuel-oil instead of gasoline. The Beardmore Tornado engines have eight cylinders of 8¼-in. bore with a 12-in. stroke and a maximum of 650 b.hp. Their paramount merit for this duty is that they burn oil of such high flash-point that it has to be heated to the temperature of boiling water before it will give off any inflammable vapor. The possibility of using hydrogen as an auxiliary fuel has been considered. Tests made on an experimental engine having four Tornado cylinders showed that hydrogen, introduced with the air, can be burned with fuel oil in such high proportion that all the gas which becomes available from the use of oil in five engines can be burned, with oil, in two engines.

The author points out that reliability, although possibly prejudiced by the use of such a new engine, has been sought in the design of the installation and in the preparations made for tests. However, owing to difficulties experienced with torsional resonance, it will

(*Continued on next left-hand page*)